TRANSVAGINAL ULTRASOUND OF THE UTEROSACRAL LIGAMENTS FOR THE DIAGNOSIS OF DEEP ENDOMETRIOSIS

By

Shae Maple

BMedRad (DR), GradDipMedSon

A thesis submitted for the degree of

Master of Research (Medical Radiation)

Unit of Allied Health and Human Performance

University of South Australia

February, 2025

Contents

Contents……..... ii

Figures……..…..... vi

Tables…….……..…..... viii

Glossary……..... ix

Abbreviations/Acronyms……..... xii

Publications and Presentations……...……..... xiv

Abstract……..... xvii

Acknowledgements……..... xx

Declaration……..... xxii

Chapter 1: Introduction **23**

1.1 Background to the Research……..… **23**

1.1.1 Presentation of Endometriosis……..... **24**

1.1.2 Diagnostic Delay of Endometriosis……..... **25**

1.1.3 Diagnosis of Endometriosis…….... **27**

1.1.3.1 Clinical and Physical Examination…….. 28

1.1.3.2 Diagnostic Imaging…… 28

1.1.3.2.1 Transvaginal Ultrasound (TVS)…….. 30

1.1.3.2.2 Models of Care for Ultrasound Diagnosis of Endometriosis in Australia…….. 31

1.1.3.3 Surgical…… 33

1.1.4 Management of Endometriosis……. 34

1.1.5 Summary……. 35

1.2 Uterosacral Ligaments…….. 35

1.2.1 USL Anatomy……. 36

1.2.2 USL Association with Endometriosis……... 36

1.2.3 USLs and Transvaginal Ultrasound……. 37

1.2.4 Site-Specific Tenderness of USLs on TVS……..... 43

1.3 Research Problem…….. 43

1.4 Statement of Aims…….. 45

1.5 Research Process……..... 46

1.6 Significance of the Research……..... 47

1.7 Outline of the Thesis……..... 47

Chapter 2: Ultrasound Characteristics and Scanning Techniques of Uterosacral Ligaments for the Diagnosis of Endometriosis: Systematic Review

2.1 Introduction and Motivation……..... 49

2.2 Published Journal Article: *JUM* (*Maple et al., 2023*)…..... 50

2.3 Discussion and Conclusion……... 68

2.3.1 Key Findings…….. 68

2.3.2 Novel Contributions to Literature……... 69

2.3.3 Strengths and Limitations…….…... 69

2.4 Updated search of the literature…….. 70

2.4.1 Conclusion of Updated Search of the Literature..... 73

Chapter 3: Ultrasound of the Uterosacral Ligaments: A Reliability Study for the Diagnosis of Endometriosis in Australian Non-Specialised Medical Imaging and Radiology Settings

3.1 Introduction and motivation…… 74

3.2 Published Journal Article: *AJUM (Maple et al., 2025*)**…... 75**

3.3 Discussion and Conclusion……... 87

3.3.1 Key Findings……..... 87

3.3.2 Novel Contributions to Literature……... 87

3.3.3 Strengths and Limitations……..... 88

Chapter 4: Relationship Between Ultrasound Diagnosis, Symptoms and Pain Scale Score on Examination in Patients with Uterosacral Ligament Endometriosis

4.1 Introduction and Motivation……..……..... 89

4.2 Published Journal Article: *JCM (Maple et al., 2024)*.....….. **90**

4.3 Discussion and Conclusion……..... 106

4.3.1 Key Findings……..... 106

4.3.2 Novel Contributions to Literature……... 106

4.3.3 Strengths and Limitations……..... 106

Chapter 5: Summary and Conclusion

5.1 Summary of Main Findings of Thesis…..……... 108

5.2 Thesis Overall Contribution to the Literature…..... 109

5.3 Limitations of Thesis……..... 110

5.4 Future Work……..... 110

5.5 Thesis Conclusion……..... 111

References: *Not included in published papers*…… **113**

Appendix **120**

Appendix 1: Systematic Review Search Strategy…… 121

Appendix 2: Data Collection - *Observer Questionnaire*……. 122

Appendix 3: Data Collection - *SST Scoring Matrix*…… 123

Appendix 4: Data Collection - *McGill Pain Scale questionnaire used to develop the SST data collection template*……. 124

Appendix 5: Raw Data - *USL Images: patient participant data collection*…….... 125

Appendix 6: Raw Data - *SST Score: patient participant data collection*……..……..... 126

Appendix 7: Ethics Completion…… 127

Appendix 8: Statement of Authorship - *Ultrasound characteristics and scanning techniques of uterosacral ligaments for the diagnosis of endometriosis*……. 131

Appendix 9: Statement of Authorship - *Ultrasound of the Uterosacral Ligaments: A Reliability Study for Diagnosing Endometriosis in Australian Non-Specialised Medical Imaging and Radiology Settings*……..... 133

Appendix 10: Statement of Authorship - *Relationship Between Ultrasound Diagnosis, Symptoms and Pain Scale Score on Examination in Patients with Uterosacral Ligament Endometriosis*…… 136

Figures

Figures from published works in this thesis are excluded from the list.

Figure 1. Pathways to diagnostic delay for endometriosis……... 26

Figure 2. The recommended diagnostic process for endometriosis from the The Royal Australian College of General Practitioners as per the European Society of Human Reproduction and Embryology (2022) guidelines…….. 27

Figure 3. Drawings of the female pelvic anatomy in the axial **(a)** and sagittal **(b)** planes show the locations of multiple endometriotic lesions. The round black lesion in the right ovary in a represents an endometrioma. The lesions with irregular margins are indicative of deep endometriosis…… 29

Figure 4. Bladder endometriosis demonstrated on MRI **(a)** sagittal and **(b)** coronal. T2- weighted MR images show a well-defined low-signal-intensity bladder wall nodule (black arrow) projecting into the lumen. Thickening of the anterior uterine serosa (white arrows in b) is also seen……. 29

Figure 5. Graphic demonstration of transvaginal ultrasound being performed of the pelvic anatomy……... 30

Figure 6. Typical appearances of normal and endometriosis ultrasound findings **(a)** Sagittal transvaginal Ultrasound with free fluid in pouch of

Douglas versus **(b)** Retroflexed uterus with large DE rectal nodule (green arrows). And **(c)** TVS of a normal ovary and uterus (arrows) versus **(d)** endometrioma with homogeneous low-level (ground glass) echoes (white arrows) and fluid-fluid level (black arrows) …… 32

Figure 7. Laparoscopy images showing normal anatomy of the female pelvis, with no evidence of endometriosis…….. 33

Figure 8. Laparoscopy images with extensive adhesions and partial obliteration of Pouch of Douglas due to deep endometriosis, **(a)** further showing endometriosis of the uterosacral ligaments and **(b)** with endometriosis of the rectum and sidewalls……... 34

Figure 9. Anatomical definition of the uterosacral ligament……..... 37

Figure 10. Laparoscopic Photographs Depicting Normal Pelvic Anatomy…. 39

Figure 11. Illustration showing how to position the transvaginal sonography transducer to assess the uterosacral ligaments based on an **(A)** anteverted uterus, posterior fornix transducer position and **(B)** retroverted uterus, posterior fornix transducer position……. 40

Figure 12. Sonographic images depicting normal anatomy of a USL, represented by the hyperechoic band of tissue close in proximity to the TVS probe……..... 41

Figure 13. Endometriosis of the USLs in a 26-year-old woman. **(a)** Axial transvaginal US image shows a small hypoechoic nodule (arrowheads) near the insertion of the left uterosacral ligament. **(b)** Laparoscopic view depicts. focal infiltration and retraction of the left uterosacral ligament (dashed oval) …….. 42

Figure 14. The research process…… 46

Tables

Tables from published works in this thesis are excluded from the list.

Table 1. Symptoms of endometriosis…… 25

Table 2. Reasons for delayed diagnosis of endometriosis…… 26

Table 3. The systematic, four step approach for TVS assessment of endometriosis as proposed by The International Deep Endometriosis Analysis (IDEA) consensus……. 31

Table 4. Summary of ultrasound criteria and technique descriptions used studies from the updated search of the literature…….. 70

Table 5. Overview of the Ultrasound Characteristics Used for the Diagnosis of USL in the newly reviewed papers……... 71

Table 6. Findings of abnormal USL descriptions used in the new papers…… 72

Glossary

Note on Terminology

*The author of this thesis recognises that there are individuals who may be affected by endometriosis who are non-binary and/or or transgender, who do not identify with the term **female**, who do not menstruate, or who have undergone hysterectomy. Efforts have been made to use inclusive gender-affirming language, however at points where the terms **female** or **reproductive age** are used in this thesis, it is to maintain consistency with the existing literature. Its use is not intended to exclude or marginalize any individual affected by endometriosis.*

Adenomyosis. A condition in which tissue similar to the lining of the uterus (endometrial tissue) grows into the muscular wall of the uterus.

Australasian Competency Framework for sonographers. Competency framework containing four significant components: sonographer competency standards, sonographer knowledge, sonographer attitudes and a holistic competency matrix.

Deep Endometriosis/Deep Infiltrative Endometriosis. Subtype of endometriosis characterised by lesions in the abdomen, extending on or under the peritoneal surface, which are frequently nodular and invasive in nature.

Dyschezia. Pain with opening bowel.

Dysmenorrhoea. Pain with menstrual periods.

Dyspareunia. Pain with sexual intercourse.

Dysuria. Pain with urination

Endometriosis. A disease characterised by the presence of endometrium-like epithelium and/or stroma outside the endometrium and myometrium, usually with an associated inflammatory process.

Endometriosis Specialist Centre/Tertiary Centre. A specialist health facility providing multidisciplinary care for the diagnosis, treatment and ongoing management of endometriosis.

Gynaecologist. A medical doctor specialising in the health of the female reproductive tract.

Hyperechoic. Ultrasound appearance of a structure that is brighter than surrounding structures due to a high echo signal.

Hypoechoic. Ultrasound appearance of a structure that is less bright than surrounding structures due to less echoes.

Hysterectomy. Removal of the uterus

Laparoscopy. Surgical technique used to identify and/or remove endometriosis.

National Action Plan for Endometriosis. Australian Government action plan to acknowledge and address the health burden of endometriosis.

Radiologist. A medical doctor specialising in medical imaging and the interpretation of medical images including ultrasound scans.

Site-Specific Tenderness. Replication of pain symptoms associated with endometriosis during ultrasound scanning by using gentle transductor pressure.

Soft Markers. Ovarian mobility and site-specific tenderness assessed during transvaginal ultrasound examination which can be suggestive of superficial endometriosis.

Sonographer. An accredited allied health professional specialising in the use of ultrasound imaging to acquire images and videos for the purpose of diagnosing disease.

Sonologist. A medical doctor specialising in the performance and interpretation of ultrasound imaging.

Ultrasound. A diagnostic imaging modality utilising high frequency sound waves to construct images of organs of the human body.

Abbreviations / Acronyms

AC_1 agreement coefficient

ASAR Australia Sonographers Accreditation Registry

ASRM American Society of Reproductive Medicine

ASUM Australian Society of Ultrasound in Medicine

COCP combined oral contraceptive pill

CI confidence interval

CT computed tomography

DE deep endometriosis/ deep infiltrating endometriosis

DF Degrees of freedom

ESHRE European Society for Human Reproduction and Embryology

GnRH-a gonadotropin releasing hormone agonists

GRRAS Guidelines for Reporting Reliability and Agreement Studies statement

Hx history

IDEA International Deep Endometriosis Analysis

LSCS Lower section Caesarean section.

LUSL left uterosacral ligament

mm millimetres

MRI magnetic resonance imaging

(n) sample size

NSAID non-steroidal anti-inflammatory drugs

OCP oral contraceptive pill

OE ovarian endometriosis/ ovarian endometriomas

POD pouch of Douglas

PPI Present Pain Intensity

PRI Pain Rating Index

PVF posterior vaginal fornix

RACGP The Royal Australian College of General Practitioners

RANZCOG The Royal Australian and New Zealand College of Obstetricians and Gynaecologists

RUSL right uterosacral ligament

RVS rectovaginal septum

SE superficial endometriosis

SF-MPQ short form McGill Pain Scale questionnaire

STROBE The Strengthening the Reporting of Observational studies in Epidemiology guidelines

SST site specific tenderness

TU torus uterinus

TVS transvaginal ultrasound

USL uterosacral ligament

WES World Endometriosis Society

Publications and Presentations

Peer-Reviewed Publications

Maple, S., Chalmers, K.J., Bezak, E., Henry, K. and Parange, N., Ultrasound Characteristics and Scanning Techniques of Uterosacral Ligaments for the Diagnosis of Endometriosis**.** *Journal of Ultrasound in Medicine*. **2023;** 42: 11931209. https://doi.org/10.1002/jum.16129

Maple, S., Bezak, E., Chalmers, K.J., and Parange, N., Ultrasound of the Uterosacral Ligaments: A Reliability Study for Diagnosing Endometriosis in Australian Non-Specialised Medical Imaging and Radiology Settings**.** Australas J Ultrasound Med, 28: e12420. **2025;** https://doi.org/10.1002/ajum.12420

Maple S, Bezak E, Chalmers KJ, Parange N., Relationship Between Ultrasound Diagnosis, Symptoms and Pain Scale Score on Examination in Patients with Uterosacral Ligament Endometriosis. *Journal of Clinical Medicine*. **2024;** 13(22):6901. https://doi.org/10.3390/jcm13226901

Awards and Recognition

Top Downloaded Article: Awarded as one of the most downloaded during its first 12 months in publication in JOURNAL OF ULTRASOUND IN MEDICINE: Ultrasound Characteristics and Scanning Techniques of Uterosacral Ligaments for the Diagnosis of Endometriosis.

Invited Presentations and Media

2025 World Endometriosis Society World (WES) Congress: Sydney, Australia. Abstract Presentation: Maple S, Bezak E, Chalmers KJ, Parange N. (2024): Ultrasound of Uterosacral Ligaments: A Reliability Study for the Diagnosis of Endometriosis in Australian Non-Specialised Medical Imaging and Radiology Settings

2025 World Endometriosis Society World (WES) Congress: Sydney, Australia. Abstract Presentation: Maple S, Bezak E, Chalmers KJ, Parange N. (2024): Relationship Between Ultrasound Diagnosis, Symptoms and Pain Scale Score on Examination in Patients with Uterosacral Ligament Endometriosis

2025 Australian Society of Medical Imaging and Radiation Therapy (ASMIRT) Conference: Adelaide, Australia. Abstract Presentation. Caitlyn Wilke, Shae Maple, K Jane Chalmers, Sarah McMullen-Roach, Nayana Parange (2025), Inclusive language and understanding of transvaginal ultrasound experiences in gender diverse patients. ASMIRT/NZMIRT.

2024 International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) Conference: Budapest, Hungary. Abstract Presentation. Deslandes, A., Avery, J., Leonardi, M., O'Hara, R., Maple, S., Chen, H., Knox, S., Panuccio, C., Lo, G., Hull, M.L. and Condous, G. (2024), EP24.30: Pilot study of intra- and interoperator agreement of a proposed image quality scoring system for transvaginal ultrasound images. Ultrasound Obstet Gynecol, 64: 353-353. https://doi.org/10.1002/uog.29036

2024 Parliamentary Select Committee on Endometriosis: House of assembly. Parliament of South Australia. Adelaide, Australia. Speaker for public hearing for the enquiry into diagnosis of endometriosis

2022 Australasian Society for Ultrasound in Medicine (ASUM) Conference: Adelaide, Australia. Speaker: Breaking Bad News in Obstetric Ultrasound; Speaker: Introducing Endometriosis into your practice; Chair: Deep Dive into Endometriosis; Chair: Gynaecology Workshop; Chair: Patient Centred Care

Media: Mind the Gap with Endometriosis: sufferers face unexpected costs**:** https://www.unisa.edu.au/media-centre/Releases/2022/mind-the-gap-with-endometriosis-sufferers-face-unexpected-costs/

Abstract

Background

Endometriosis is a common and painful gynaecological condition averaging 6.4years to diagnose. While RANZCOG prefers laparoscopic surgery as the current gold standard in diagnosis of endometriosis, ESHERE now recommends transvaginal ultrasound (TVS) as a primary diagnostic tool. This is due to its accuracy of detecting deep endometriosis (DE), the limitations of surgery such as invasiveness, cost and after surgical recovery time of surgery and its ability to assist surgeons in the planning and management of patients, especially when there is limited visualisation in the posterior compartment.

Uterosacral ligaments (USL) are located in the posterior compartment and are one of the first and most common places that endometriosis deposits. The current guidelines by the International Deep Endometriosis Analysis group (IDEA) for TVS imaging recommend assessment of anatomic structures in the posterior compartment including the USLs and site-specific tenderness (SST) however, currently there is limited description around pain descriptors and their application in endometriosis diagnosis. These pain symptoms associated with endometriosis can be replicated by SST-TVS by using gentle transductor pressure.

Currently, there is no validated criteria for USLs in the ultrasound diagnosis of endometriosis. Therefore, this thesis summarises the available diagnostic criteria available and then explores the reliability of TVS ultrasound characteristics of normal

and abnormal USLs as well as investigate if SST descriptors can positively assist diagnosing endometriosis on TVS.

Objective

To investigate the ultrasound techniques and characteristics of normal and abnormal USLs in the diagnosis of endometriosis and associated site-specific tenderness. And, to assess the intra and interobserver reliability of the established criteria and SST pain scale benefit between experienced and less experienced examiners in an Australian general ultrasound imaging practice.

Discussion

Firstly, a systematic review of current literature was performed that identified that published literature reporting ultrasound criteria of USLs with DE shows descriptive reporting only with no interobservational or intraobservational validation with inconsistent descriptors and varying terminology. Data was from tertiary centres therefore cannot be applied to a general setting. It was established that there needs to be clear and reproducible ultrasound criteria to improve reporting standardisation of the diagnosis of endometriosis as well as sonographer and radiologist education in general settings.

Following this, the second study was an interrater study that aimed to assess interrater reliability in evaluation of TVS in endometriosis by sonographers and radiologists in an Australian general imaging department. Differences were evaluated between experienced and less experienced examiners. Ultrasound images were collected from 42 patients and sorted in two groups: Twelve (12) of who presented with no history or symptoms of endometriosis while 30 patients presented with medically diagnosed endometriosis, either via laparoscopy or clinically diagnosed by a gynaecologist. Six professionals (5 sonographers and 1 radiologist) reviewed the 42 patient participant images of USLs over 2 sessions. Clear criteria for assessment of USLs were provided based on the previously published systematic review. A high interobserver agreement was established of sonographers and radiologists in a general imaging department in Australia for identifying ultrasound characteristics for USLs for diagnosing DE. Results also showed that there is consistency in identifying a thickened USL. Overall, experienced and inexperienced operators achieved similar results when performing an ultrasound assessment of the USLs. However, there is no consensus on where USL be measured.

Even so, a thickened USL can prompt further extension of the pelvic scan to look for other markers of endometriosis.

Finally, the third study was an observational study of 42 women who underwent TVS for endometriosis. This aimed to evaluate patient pain descriptors, using the validated short form McGill Pain Scale questionnaire in the ultrasound diagnostic evaluation of endometriosis of the USLs. The professional observers from study 2 were provided the additional pain scale descriptors where it was investigated if additional patient SST pain score information alters a diagnostic decision of endometriosis of imaging professionals when diagnosing endometriosis on TVS. Results demonstrated that patients with endometriosis history do have significantly higher pain scores on TVS compared to patients with no history of endometriosis. Inclusion of SST to TVS shows promise in diagnosis of endometriosis, with a higher ability to correctly identify endometriosis with the pain scale information. However, this needs to be interpreted with caution as not statistically significant.

Conclusion

With clear criteria that includes reproducible scanning techniques and diagnostic criteria, there is high interrater reliability between sonographers and radiologists even in general practice settings. The addition of SST as a pain scale can help diagnosis, especially in settings where specialised skills for ultrasound diagnosis of endometriosis are limited. Education to establish these techniques and validated protocols in general imaging settings followed by implementation could potentially result in reduced diagnostic delays however further research is warranted to explore this further.

Acknowledgements

I would like to acknowledge individuals in the transgender community and people who are non-binary living with endometriosis who might not identify as women. Efforts have been made to use neutral language. Where the word ‘woman’ of ‘female’ has been used, we include all people with a uterus. I would like pay my respects to the Kaurna people, Elders and country upon which the research presented within this thesis was carried out. I pay my respects to Elders past, present and emerging.

I sincerely acknowledge the support of the Australian Government Research Training Program Scholarship and extend my gratitude to the University of South Australia for their assistance. The completion of this thesis would not have been possible without the guidance and support of my supervisory team; Professor Nayana Parange, Professor Eva Bezak, and Dr. Jane Chalmers. I am deeply grateful for your mentorship throughout this journey and will always value the knowledge and insights you have shared with me.

Thank you to the people who have helped along the way. Thank you to Kate Henry for your hours working through the literature review data. Thank you to Adrian Esterman expert assistance with the statistical analysis in this thesis, and to Alison Deslandes for friendship in this research world and introducing me in your endometriosis network, always making me feel welcome.

Thank you to Doctor Karen Shand for teaching me how to perform an ultrasound to detect endometriosis all those years ago. Without your introduction to this important technique, my interest would never have been sparked and this project would never have occurred. I miss working with you very much. To Doctor Steven Knox, thank you for your support

of this project and your assistance in ethical considerations for participant recruitment to take place at Benson Radiology. I look forward to our future work together.

To the 6 sonographers and radiologists who offered me their time in reviewing the ultrasound images. Your expertise and time have had an immeasurable impact on the results of this thesis. Thank you for contributing and being pioneers in hopefully more validity studies in your profession's advancement in diagnosing endometriosis.

I am deeply grateful to the 42 patients who positively and willingly allowed me to use their imaging data for this study. No words can express the most wonderful and unforeseen experience of this project: women's unconditional willingness to help other women. From all the patients suffering from this disease willing to hand over everything and anything they could to help find solutions, and to the women who despite having no personal experience with endometriosis allowed me to use their images and data with no hesitation at all with the goodwill of helping other women.

I thank you for your support and co-operation and positive attitudes to advancing women's health which ultimately allowed this project to progress to completion. I hope that our combined effort is one small step towards improving things for the next generation of people with endometriosis.

And finally, most importantly, thank you to my family Carly, Estelle, Hugo and August; for your patience, understanding and encouragement throughout, especially when I am working in the dark hours of the night.

Declaration

This thesis presents work carried out by myself and does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; to the best of my knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text; and all substantive contributions by others to the work presented, including jointly authored publications, are clearly acknowledged.

Shae Maple 3rd February, 2025



Chapter 1

Introduction

1.1 Background to the Research

Endometriosis is a benign, estrogen-dependent gynaecological condition characterised by the growth of endometrial-like tissue outside the uterus[1-3]. Commonly affecting the peritoneal cavity, ovaries, bladder, and ureters, it impacts 1 in 10 individuals[3,4] of reproductive age, equivalent to approximately 830,000 Australians[3,5] and 190 million people globally[3]. Endometriosis is associated with pain, infertility, and reduced quality of life[6], significantly affecting social relationships[6,7], work productivity[6,7] and healthcare costs. In Australia, it carries an estimated annual economic burden of $7.7 billion[8].

Despite its prevalence and impact, endometriosis diagnosis is notably delayed, averaging 6.4 years in Australia[9]. Delays often exacerbate pain, disease progression, and healthcare costs[3,8,10]. In response, the Australian Government introduced the National Action Plan[8] in 2018, aiming to improve diagnosis, care, and research, reducing the condition's physical and psychosocial impact with efforts being made for a coordinated approach to improve the methods of diagnosis to reduce diagnostic delay[8]. This research in this thesis contributes to these goals by advancing knowledge in non-invasive diagnostic methods and addressing diagnostic delays.

1.1.1 Presentation of Endometriosis

Endometriosis is a multifaceted disease with an unclear aetiology[3], involving genetic, endocrine, immunologic, pro-inflammatory[11], and environmental factors[3,11]. Retrograde menstruation, where menstrual blood flows into the peritoneal cavity[6], is one proposed mechanism. Another theory suggests the dissemination of endometrial cells via the bloodstream or lymphatic system[12]. These cells provoke immune and inflammatory responses, facilitating cellular adhesion, proliferation, and localised inflammation[11,12]. Endometriotic lesions often contain nerve fibres[11,13], contributing to severe pain[14,15], and can cause anatomy-distorting adhesions[14,15], organ immobility, and chronic pelvic pain[13,16-18]. Hormonal changes exacerbate inflammation, fibrosis, and pelvic floor dysfunction[6,19], leading to debilitating symptoms like dysmenorrhoea and dyspareunia[14,15].

The disease manifests in three primary forms categorised based on lesion type and location [7]:

1. **Deep Endometriosis / Deep Infiltrative Endometriosis (DE):** Lesions extend more than 5 mm beneath the peritoneal surface[20] and are typically nodular, invasive, and associated with fibrosis and anatomical disruption. DE affects structures such as the uterosacral ligaments, bowel, rectum, vaginal walls, rectovaginal septum, pouch of Douglas, ureters, and bladder[21,22].
2. **Superficial Endometriosis (SE):** Lesions involve ectopic growth of endometrial tissue extending less than 5 mm beneath the peritoneal surface[6,23], appearing as black-brown or light red-orange during surgery[20]. SE is found in 15–50% of women diagnosed with endometriosis[3].
3. **Ovarian Endometriomas (OE):** These are ovarian cysts formed by endometrial tissue[3], occurring in 2–10% of reproductive-age women and representing one of the most common forms of endometriosis[6].

Symptoms of endometriosis vary widely[14,24] and often do not correlate with disease severity, complicating diagnosis. Some individuals remain asymptomatic, while others experience cyclical or nonspecific symptoms that may overlap with other conditions[3]. Beyond physical symptoms, endometriosis profoundly impacts, mental and social well-being, reducing overall quality of life[7,24]. Clinical symptoms (summarised in Table 1) are considered indicative of endometriosis[2,14,19,25]:

TABLE 1. Symptoms of endometriosis.[2,7,14,19,24,25]

Clinical Pain Symptoms	Other Clinical Symptoms	Non-Clinical Symptoms
• Chronic pelvic pain • Dysmenorrhoea • Dyspareunia • Dyschezia • Dysmenorrhoea • Painful rectal bleeding • Shoulder tip pain	• Infertility • Haematuria • Cyclical scar swelling • Cyclical Cough/haemoptysis • Catamenial pneumothorax	• Depression • Feelings of isolation • Fatigue • Lack of energy

1.1.2 Diagnostic Delay of Endometriosis

Diagnosing endometriosis is challenging, with delays averaging 6.4 years in Australia[9] and up to 11 years globally[26]. These delays result in worsened pain, disease progression, and increased healthcare costs[26]. A review of the diagnostic pathway highlights bottlenecks at multiple stages, from symptom onset to formal diagnosis[26] (Figure 1).

Contributing factors as summarised in Table 2, include a lack of awareness among patients and healthcare providers, difficulties in articulating symptoms, and dismissive attitudes or misdiagnoses[26]. Many patients, despite overcoming barriers like cost or embarrassment, struggled to articulate their symptoms, leading to dismissive attitudes and frequent misdiagnoses by healthcare providers. The absence of clinical guidelines further compounded the knowledge gap among providers[26]. Additionally, the invasiveness of current diagnostic methods and the absence of standardised clinical guidelines further impede timely diagnosis. Addressing these barriers requires both educational initiatives and advancements in non-invasive diagnostic techniques.

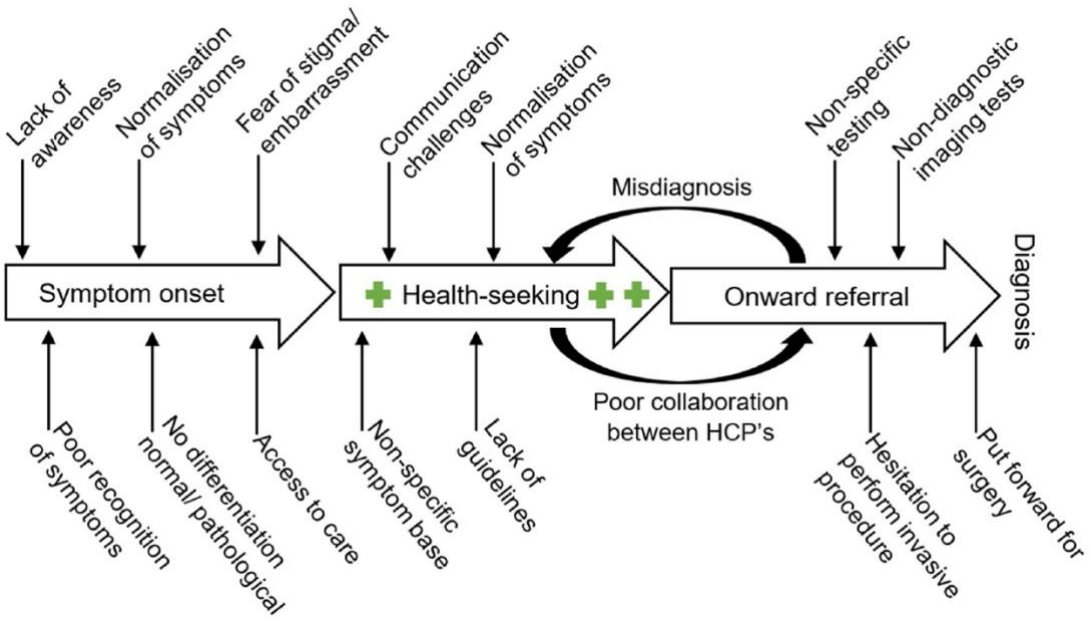


FIGURE 1. Pathways to diagnostic delay for endometriosis.[26]

TABLE 2. Reasons for delayed diagnosis of endometriosis.

Patient-centred Barriers	Healthcare Professional-centred Barriers
- Difficulty accessing specialist services[27,28]. - Tolerance of symptoms[10] hence preferring to self-manage symptoms[27]. - Feeling embarassed[10], stigmatisation[10] or afraid and/or the belief that providers would not help them[27]. - Being unaware of treatment options[27]. - Uncertainty of normal versus abnormal symptoms[10] including the assumption that painful periods are a normal[27] or not emphasising the severity of their symptoms[28].	- Normalising of patient symptoms[10] - Dismissal of symptoms[6] or attributing these to urologic or gastrointestinal issues or psychological problems.[2,10,6] - Variable and fluctuating symptoms that can overlap with other common conditions characterised by pelvic-abdominal pain and infertility[10,29]. - Reliance on inadequate diagnostic methods[10] including unawareness that laparoscopy is no longer considered the only option in the diagnosis of endometriosis and that imaging (TVS or MRI) should be part of the primary work up[7]. - Inconsistent approach to the diagnosis and management of endometriosis[10].

Key: (TVS) Transvaginal ultrasound; (MRI) Magnetic resonance imaging.

1.1.3 Diagnosis of Endometriosis

Effective diagnosis of endometriosis relies on a combination of clinical history, physical examination, imaging, and surgery. Each method has distinct strengths and limitations, forming a continuum in the diagnostic process.

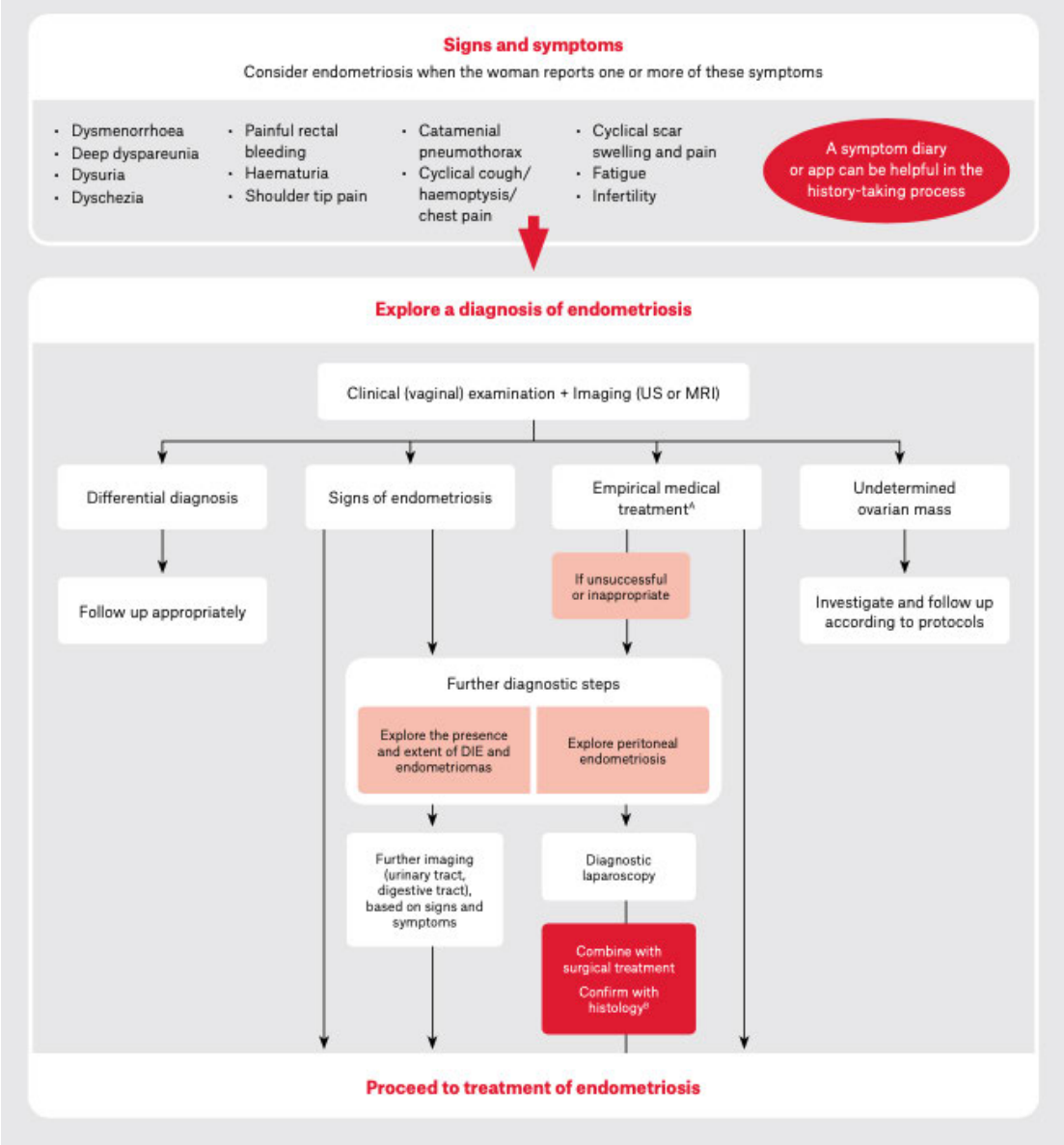


FIGURE 2. The recommended diagnostic process for endometriosis from The Royal Australian College of General Practitioners (RACGP)[14] as per the European Society of Human Reproduction and Embryology (2022)[7] guidelines as summarised by (Crump et al, 2024).[14]

Endometriosis causes severe pain linked to lesion location therefore accurate lesion mapping is crucial during assessment[2]. While surgery with histopathological analysis was the diagnostic gold standard[3] for this, the European Society of Human Reproduction and Embryology (2022)[7] now recommends non-invasive imaging, such as TVS, to reduce delays and invasiveness[30] (Figure 2).

Combining symptoms, physical exam findings, and imaging allows for a nonsurgical presumptive diagnosis and is currently the preferred approach for individuals with mild to moderate symptoms, those opting for low-risk treatments (e.g., NSAIDs, hormonal contraception), or those avoiding surgery[31].

1.1.3.1 Clinical and Physical Examination

Non-invasive endometriosis diagnosis relies on patient history, clinical signs, and symptoms such as dysmenorrhea, pelvic pain, dyspareunia, infertility, and non-gynaecological symptoms like dyschezia or haematuria[30]. Physical examination includes pelvic and abdominal assessments[30], speculum examination[3,30], and vaginal palpation for tenderness, organ immobility, or nodules[30]. However, diagnostic accuracy is low, and a normal exam does not rule out endometriosis[31]. Biomarkers, such as serum CA125[3,7], lack sufficient evidence for clinical use, though research is ongoing[7,11,14,31].

1.1.3.2 Diagnostic Imaging

Transvaginal ultrasound (TVS) and Magnetic Resonance Imaging (MRI) are the most employed diagnostic imaging modalities in endometriosis currently[30]. Figure 3 depicts the numerous locations where endometriotic lesions can develop. Imaging can strongly suggest an endometriosis diagnosis and aid surgical planning but cannot replace histologic confirmation. Ultrasound and MRI can identify lesions, though negative imaging does not rule out the disease, especially superficial peritoneal endometriosis[31].

MRI is a non-invasive tool for imaging endometriosis, particularly in complex cases requiring surgical planning[3,30]. Posterior DE appears as low-signal-intensity areas or nodules on T2-weighted MRI[32]. DE lesions often have signal intensity similar to surrounding structures, increasing the risk of false-positive diagnoses from misinterpreting normal anatomy[32]. While its accuracy for DE is comparable to TVS[33], MRI offers multiplanar imaging and a broader field of view, enabling imaging of multifocal or extra-pelvic lesions[30] (Figure 4). It is less invasive, uses abdominal coils[34],

and allows off-site expert analysis[30]. However, MRI lacks dynamic pelvic assessment, has safety contraindications (e.g., metal implants, claustrophobia)[30], and in Australia, is only subsidised for bowel or bladder DE, limiting accessibility[14]. Protocol variability[30] and the absence of standardised reporting guidelines for DE remain challenges in diagnosis for endometriosis[34].

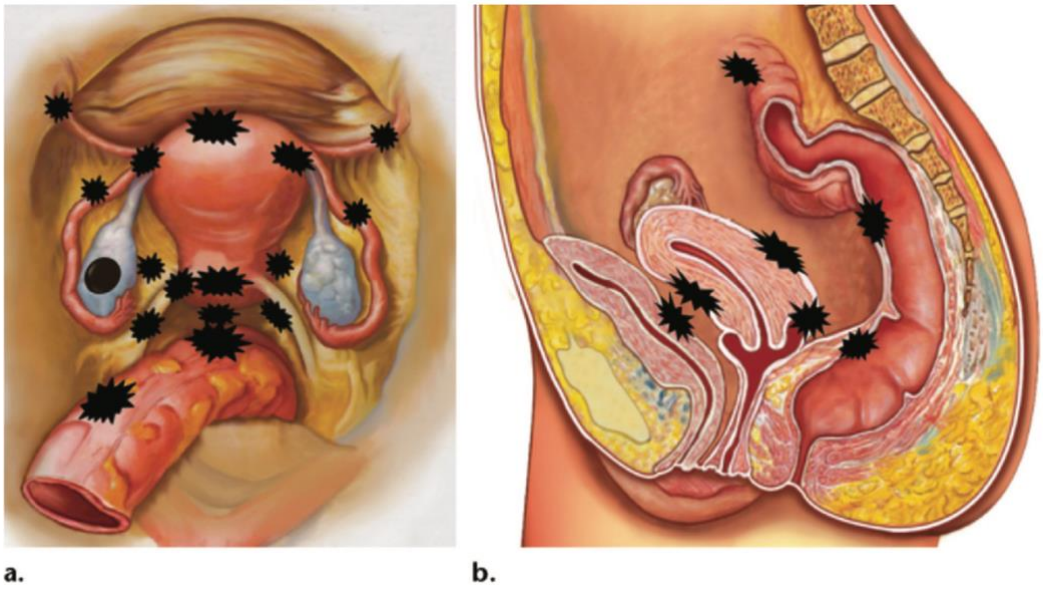


FIGURE 3. Drawings of the female pelvic anatomy in the axial **(a)** and sagittal **(b)** planes show the locations of multiple endometriotic lesions. The round black lesion in the right ovary in **(a)** represents an endometrioma. The lesions with irregular margins are indicative of deeply infiltrating endometriosis (Chamié et al, 2022).[35]

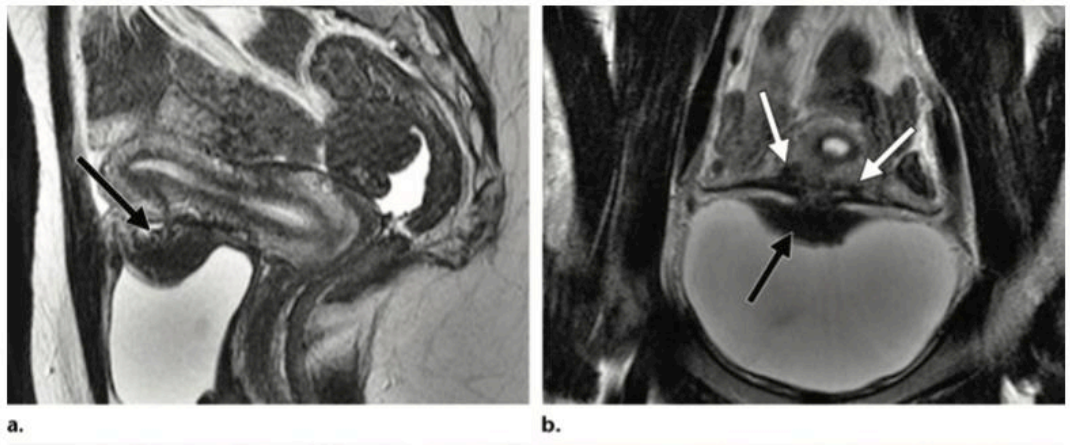


FIGURE 4. Bladder endometriosis demonstrated on MRI **(a)** sagittal and **(b)** coronal. T2-weighted MR images show a well-defined low-signal-intensity bladder wall nodule (black arrow) projecting into the lumen. Thickening of the anterior uterine serosa (white arrows in b) is also seen (Chamié et al, 2022).[35]

1.1.3.2.1 Transvaginal Ultrasound (TVS)

Ultrasound emits and receives high-frequency sound waves to construct a grey scale image of the required anatomy. TVS involves placing a high-frequency (9 MHz) transvaginal transducer into the vagina[36] (Figure 5) which can closely image the pelvic anatomy. It is common in gynaecological imaging, widely available, low cost and well tolerated by most[37]. Routine TVS assesses the uterus, ovaries, and pelvic fluid[3,38], possibly detecting endometriomas[39]. In the early 2000s, reports began highlighting the use of TVS in diagnosing DE[1,40-43] and in 2016, the International Deep Endometriosis Analysis (IDEA) consensus paper[22] was published outlining methods for detecting DE and adhesions by evaluating pelvic organ mobility and site-specific tenderness. This includes a four-step assessment of all anatomic structures in the anterior compartment (bladder, ureter) and posterior compartment (bowel, USLs, RVS, PVF and POD) for DE and assessment of pelvic organ mobility as listed in Table 3. The guidelines also state that the examination should be extended to assess the pelvic organs for mobility and site-specific tenderness (SST)[22].

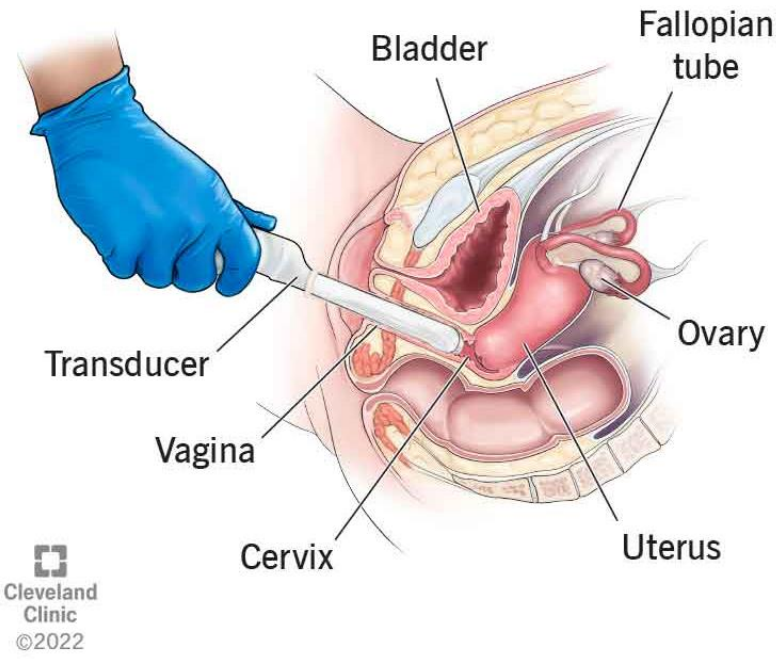


FIGURE 5. Graphic demonstration of transvaginal ultrasound being performed of the pelvic anatomy (Cleveland Clinic, 2022).[44]

TABLE 3. The systematic, four step approach for TVS assessment of endometriosis as proposed by IDEA consensus (Guerriero et al, 2016).[22]

Step	TVS Assessment	Signs of Endometriotic Disease on TVS
1	Uterus and ovaries	Adenomyosis Ovarian endometriomas
2	Ovarian mobility and site-specific tenderness	Ovarian adhesions SST to indicate DE
3	Uterine sliding sign	Obliteration of POD
4a	***Anterior compartment*** - Bladder - Ureters - Vesicouterine space	Deposit nodules of DE in the anterior compartment
4b	***Posterior compartment*** - Posterior vaginal wall - Uterosacral ligaments - Rectosigmoid colon - Pouch of Douglas - Rectovaginal septum	Deposits nodules of DE in the posterior compartment

Key: (TVS transvaginal ultrasound; (IDEA) International Deep Endometriosis Analysis Group; (SST) site-specific tenderness; (DE) deep endometriosis; (POD) pouch of Douglas.

1.1.3.2.2 Models of Care for Ultrasound Diagnosis of Endometriosis in Australia

At this stage, when performing ultrasound for endometriosis diagnosis and management, there are 3 models of imaging care exist:

1. ***Sonologist only:*** who is usually a gynaecologist with specialised obstetrics/gynaecology-focused ultrasound training and optimal knowledge of endometriosis. This model commonly functions in a specialised clinic.
2. ***Sonologist and Sonographer:*** the specialist trained sonographer performs the ultrasound while the sonologist is generally simultaneously performing and interpreting the ultrasound within the clinical consultation.
3. ***Sonographer and Radiologist***: the sonographer performs the ultrasound, captures images and videos, and these are interpreted remotely by a radiologist. This model commonly functions in a general imaging clinics.

With advancing knowledge, TVS is increasingly utilised in pre-surgical planning for gynaecological surgery[30]. This approach enables gynaecological surgeon-sonologists to combine clinical expertise with ultrasound as an extension of the physical exam, particularly for diagnosing and managing endometriosis[30]. Literature consistently highlights the accuracy of TVS in identifying endometriosis (Figure 6).

However, barriers remain in general practice. While studies confirm the high accuracy of TVS in DE[21,45-49], most data are derived from specialist endometriosis centres, where scans are predominantly performed by experienced gynaecologists or sonologists[45]. In Australia, the Australasian Competency Framework for Sonographers[50] classifies scanning for endometriosis as an advanced skill rather than a core competency. As a result, Australian sonographers in general practice often lack the specialised training required to perform these scans for endometriosis[37].

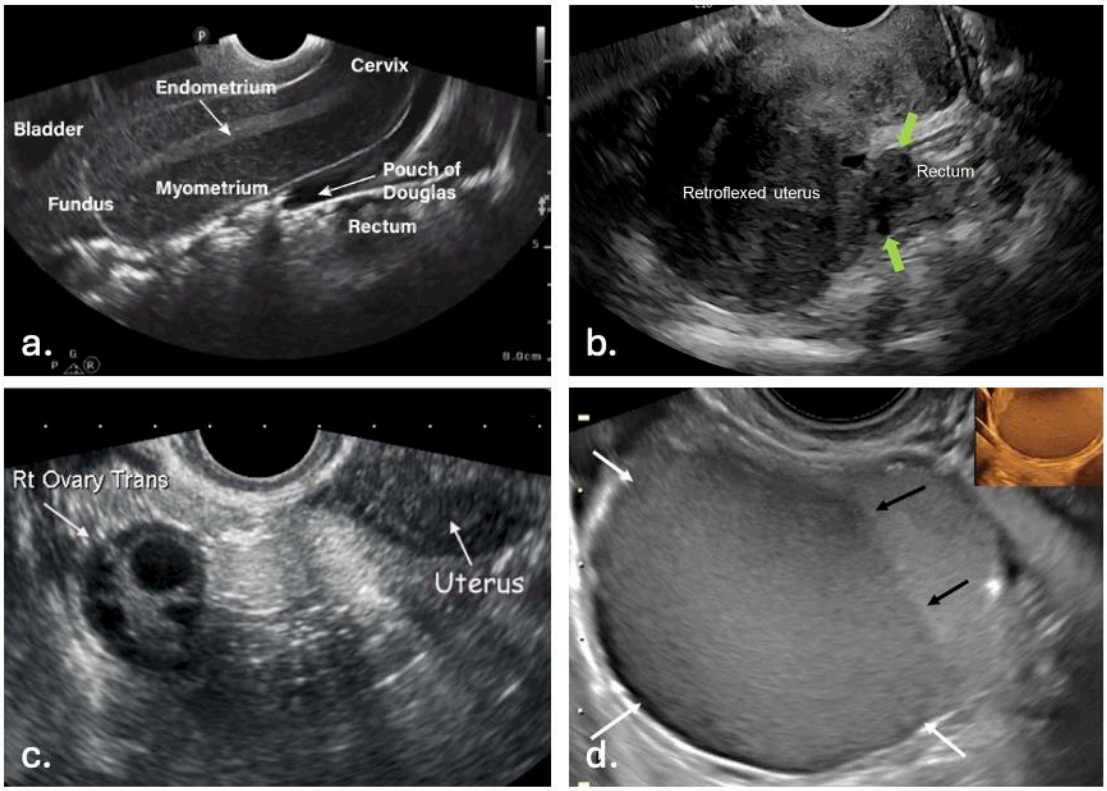


FIGURE 6. Typical appearances of normal and endometriosis ultrasound findings. **(a)** Sagittal transvaginal Ultrasound with free fluid in pouch of Douglas[51] versus, **(b)** Retroflexed uterus with large DE rectal nodule (green arrows)[36]. And **(c)** TVS of a normal ovary and uterus (arrows)[52] versus **(d)** endometrioma with homogeneous low-level (ground glass) echoes (white arrows) and fluid-fluid level (black arrows).[21] - Young et al, 2020[36], Ultrasoundpaedia, 2024[52], Young et al[36], 2024[21].

Furthermore, the expectations for sonographers regarding endometriosis scanning remain unclear, limiting its availability in many general imaging clinics[37]. Additionally, there is limited evidence on the accuracy of applying the IDEA[22] guidelines in general outpatient settings, where disease prevalence is lower and scans are performed by sonographers without surgical expertise[45].

1.1.3.3 Surgical

Surgical diagnosis via laparoscopy, combined with histological biopsy, is the preferred approach for severe cases, individuals unresponsive to initial therapies, or when definitive confirmation is required[3]. One of its key advantages is the ability to diagnose and treat simultaneously[30,31], as operative laparoscopy allows for lesion removal during the same procedure. This approach reduces the need for multiple surgeries, benefiting both patients and healthcare systems[30].

Laparoscopy is the standard surgical method for endometriosis, with open laparotomy being less common. During the procedure, surgeons visually assess the pelvic anatomy

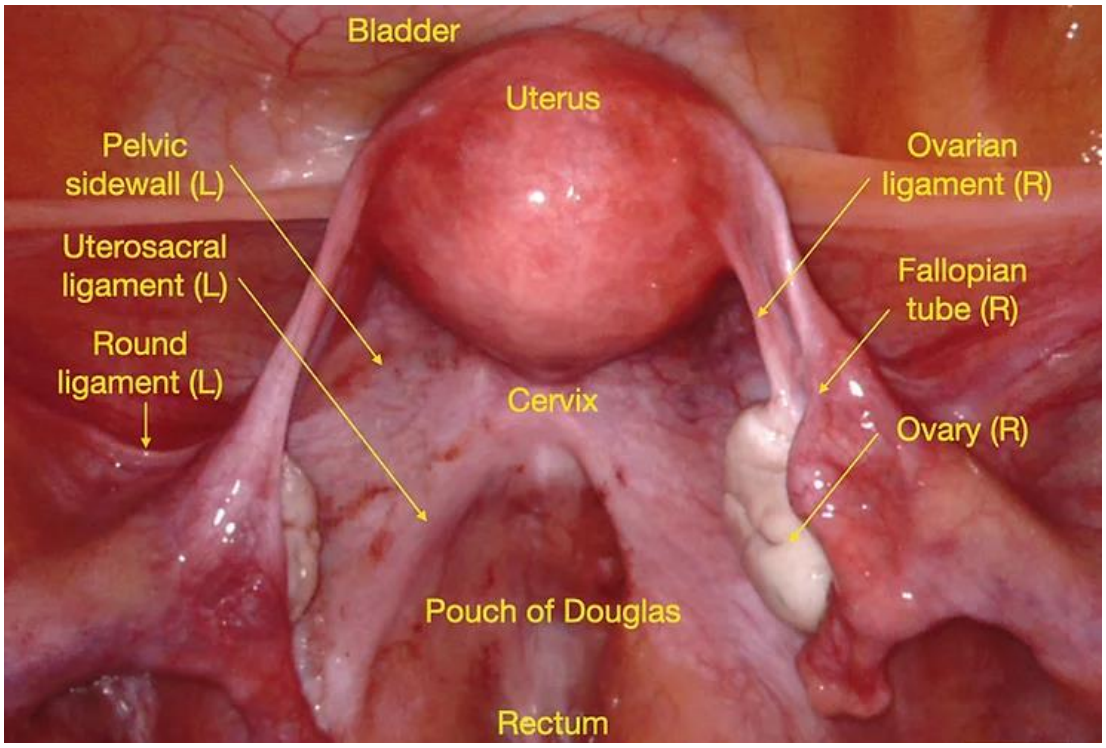


FIGURE 7. Laparoscopy images showing normal anatomy of the female pelvis, with no evidence of endometriosis (Endometriosis Australia[53]).

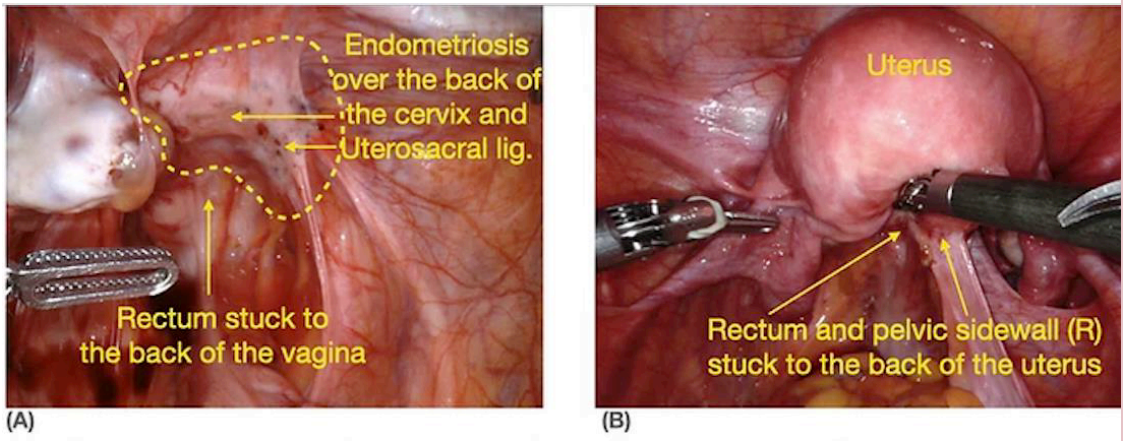


FIGURE 8. Laparoscopy images with extensive adhesions and partial obliteration of Pouch of Douglas due to deep endometriosis, **(a)** further showing endometriosis of the uterosacral ligaments and **(b)** with endometriosis of the rectum and sidewalls (Endometriosis Australia[53]).

to identify endometriotic lesions (Figure 7). DE presents unique challenges, often requiring excision by highly skilled laparoscopic surgeons[20]. Extensive adhesions can obscure deposits[20] (Figure 8) and distort normal anatomy, requiring a systematic evaluation of both pelvic and abdominal structures[3]. In cases where no lesions are visible, histological sampling is essential to confirm or exclude the diagnosis[3,54].

While laparoscopy offers valuable diagnostic and therapeutic benefits, it is invasive, costly, and not without risks[31]. These factors emphasise the importance of accurate preoperative imaging to guide surgical planning, ensure thorough lesion mapping, and minimise complications.

1.1.4 Management of Endometriosis

Endometriosis is a complex, chronic condition requiring long-term multidisciplinary management[9]. The World Endometriosis Society recommends that severe cases be treated in specialised centres[20], combining surgical, pharmacological, or self-management strategies[6].

Surgery, typically via operative laparoscopy, remains the primary treatment[2], as pharmacological and self-management approaches primarily offer symptom relief[2]. Surgery aims to remove endometrial deposits and correct adhesions[11,14], with outcomes dependent on lesion location[2] and surgical skill[11,30]. Pre-surgical imaging (TVS or MRI)

aids in planning and reduces the need for repeat procedures. Multidisciplinary teams, including advanced gynaecological surgeons, are often required[30]. While surgery can reduce pain, outcomes vary. Hysterectomy is considered when other treatments fail[14], though excising endometriomas can harm ovarian reserve[14], impacting fertility[11].

Hormonal therapies, such as combined or progestin-only contraceptives, are first-line treatments for pain management[11]. These aim to reduce symptoms, inhibit lesion progression, and restore fertility[6]. However, high costs and side effects limit their use, with some medications not covered under schemes like the Australian Pharmaceutical Benefits Scheme (PBS)[8].

Self-management strategies, used by 60-70% of patients[14], aim to improve quality of life[37]. Despite limited evidence of efficacy[55], methods like acupuncture, physiotherapy, exercise, diet, supplements, and mindfulness provide a sense of control over the condition[14,55]. Education on self-care remains a priority, as highlighted in Australia's National Action Plan for Endometriosis.

1.1.5 Summary

Endometriosis is a complex, chronic condition with significant physical, emotional, and economic impacts. While advancements in imaging, such as TVS, are improving diagnostic accuracy, challenges remain in ensuring these techniques are accessible in general practice settings. This thesis focuses on the role of ultrasound in general medical imaging practice in Australia for diagnosing uterosacral ligament endometriosis, a common site of disease.

1.2 Uterosacral Ligaments

The uterosacral ligaments (USLs) and endometriosis are closely related due to the anatomical location of the USLs in the posterior compartment, making them one of the most common sites of DE[19,25,56,57].

Imaging in the posterior compartment is challenging due to its small anatomical area[32], including the USLs, the pouch of Douglas, the posterior border of the cervix and isthmus of the uterus, the vaginal wall and fornices, and the anterior wall of the rectum or

rectosigmoid junction[19,22,32]. Therefore, a multidisciplinary approach involving imaging, clinical, and surgical professionals is essential for the diagnosis and management of USL endometriosis[7,14,31].

1.2.1 Uterosacral Ligament Anatomy

The uterosacral ligaments are extraperitoneal supportive structures in the female pelvis that help to hold the uterus in place. These ligaments form the lateral boundaries of the rectouterine and rectovaginal spaces, extending from the uterine cervix to the sacrum, and can be anatomically divided into distal/cervical, intermediate, and proximal/sacral sections[19,25,58]. The total length of the USL ranges from 12 to 14 cm[58], with the distal cervical section the thickest portion[58] (Figure 9, Figure 10).

Composed primarily of dense connective tissue, the USLs provide both strength and elasticity. They also contain layered neurovascular structures[19,58], contributing to their multifunctional role[58]. Surrounding the USLs are the paracervical and parametrial tissues, which are fibrous and fatty connective tissues rich in vessels and nerves[19,58].

In addition to supporting the uterus and preventing prolapse[58], the USLs help maintain the position of pelvic organs and play a critical role in urinary and faecal continence. Dysfunction or weakening of these ligaments can result in uterine prolapse or incontinence.

1.2.2 Uterosacral Ligament Association with Endometriosis

Deep endometriosis is diagnosed when endometriotic lesions infiltrate deeper than 5 mm into the peritoneum[20,56,59], commonly affecting both the anterior and posterior compartments[21,22]. USL DE is common[19,25,56,57] and was first highlighted in 2003 by Chapron et al., who conducted a large observational study with surgical and histological findings, reporting that 69.2% of patients with DE had USL involvement[60].

Surgical findings have confirmed that most USL endometriotic lesions are located in the cervical section of the ligament[19]. Scioscia et al. (2011) reported that 96.3% of USL endometriosis lesions occur in this region[61]. Sonographically, the distal cervical section of the USL is easily visualised on TVS as it attaches to the posterior cervix[22,25,58], adjacent to the posteriorly positioned ultrasound transducer.

Understanding the anatomy and function of the USLs is critical for sonographers involved in the non-invasive diagnosis of endometriosis. Accurate imaging of the USLs can improve diagnosis, facilitate effective management, and aid in surgical pre-planning[25].

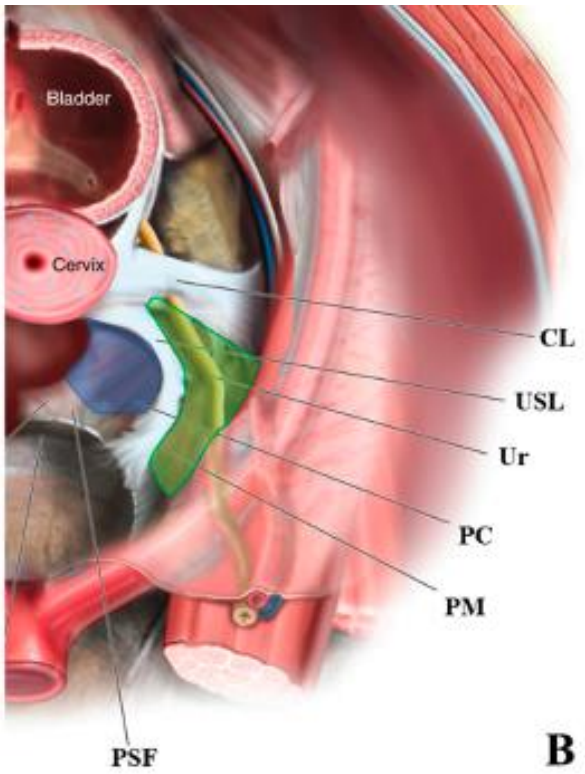


FIGURE 9. Anatomical definition of the uterosacral ligament (Scioscia et al, 2021)[19].
Key: CL, cardinal ligament; PC, paracervix; PM, parametrium; PSF, presacral fascia; Ur, ureter; USL, uterosacral.

1.2.3 Uterosacral Ligaments and Transvaginal Ultrasound

The USLs are easily accessible with TVS[19,21,62] and play a crucial role in the clinical assessment of endometriosis. Historically, it was believed by some sonographers that USLs could not be adequately visualised with ultrasound; however, along with advancing technologies, recent studies have disproven this, showing that USLs can be effectively imaged with TVS[1,25,63]. The process begins with a thorough ultrasound assessment of the pelvis, including the cervix, uterus, and ovaries[25]. The examination is then extended to the posterior compartment, where the ultrasound transducer is positioned in the posterior vaginal fornix in a longitudinal axis and rotated laterally by approximately 45

degrees[19,25,36]. This technique enables visualisation of the hyperechoic USLs[19,25,64], which are easily identified due to their proximity, although their position can vary with uterine orientation (Figure 11).

TVS can identify normal USL anatomy (Figure 12) and detect pathological changes such as thickening, nodularity, or irregular contours, which may indicate endometriosis[25] (Figure 13). The International Deep Endometriosis Analysis (IDEA)[22] group guidelines, published in 2016, recommend evaluating features such as hypoechoic thickening and irregular margins for diagnosing USL DE. However, these recommendations are not yet validated, requiring further research to establish accurate and reliable diagnostic criteria.

TVS has become a reliable, non-invasive, and rapid diagnostic tool for DE, with overall diagnostic accuracy reported as high[45,46]. Sensitivities range from 78.5% to 85.3%, specificities from 46.1% to 92.5%, and overall accuracies from 75.7% to 97%[45]. In 2022, using the IDEA[22,65] consensus methodology, TVS demonstrated a sensitivity of 88% and specificity of 79% for predicting DE[65], though accuracy varied by location. However, diagnosing DE specifically in the USLs remains less accurate[46].

When this research began in 2021, a systematic review by Deslandes et al. (2020) noted that while USL DE was commonly reported, the accuracy of TVS in detecting USL DE remained low, with sensitivities under 70%[45]. Similarly, a meta-analysis by Gerges et al. (2021) found pooled sensitivities of 60% and specificities of 95%[46]. One explanation for this relatively low sensitivity was the lack of validated criteria for ultrasound diagnosis of USL DE.

Recent advancements have improved diagnostic accuracy. A study by Freger et al. (2023) reported sensitivities of 82.6%, specificities of 100%, and overall accuracies of 94.4%[47]. This improvement was attributed to refined sonographic techniques, such as positioning the TVS probe in the posterior vaginal fornix[47].

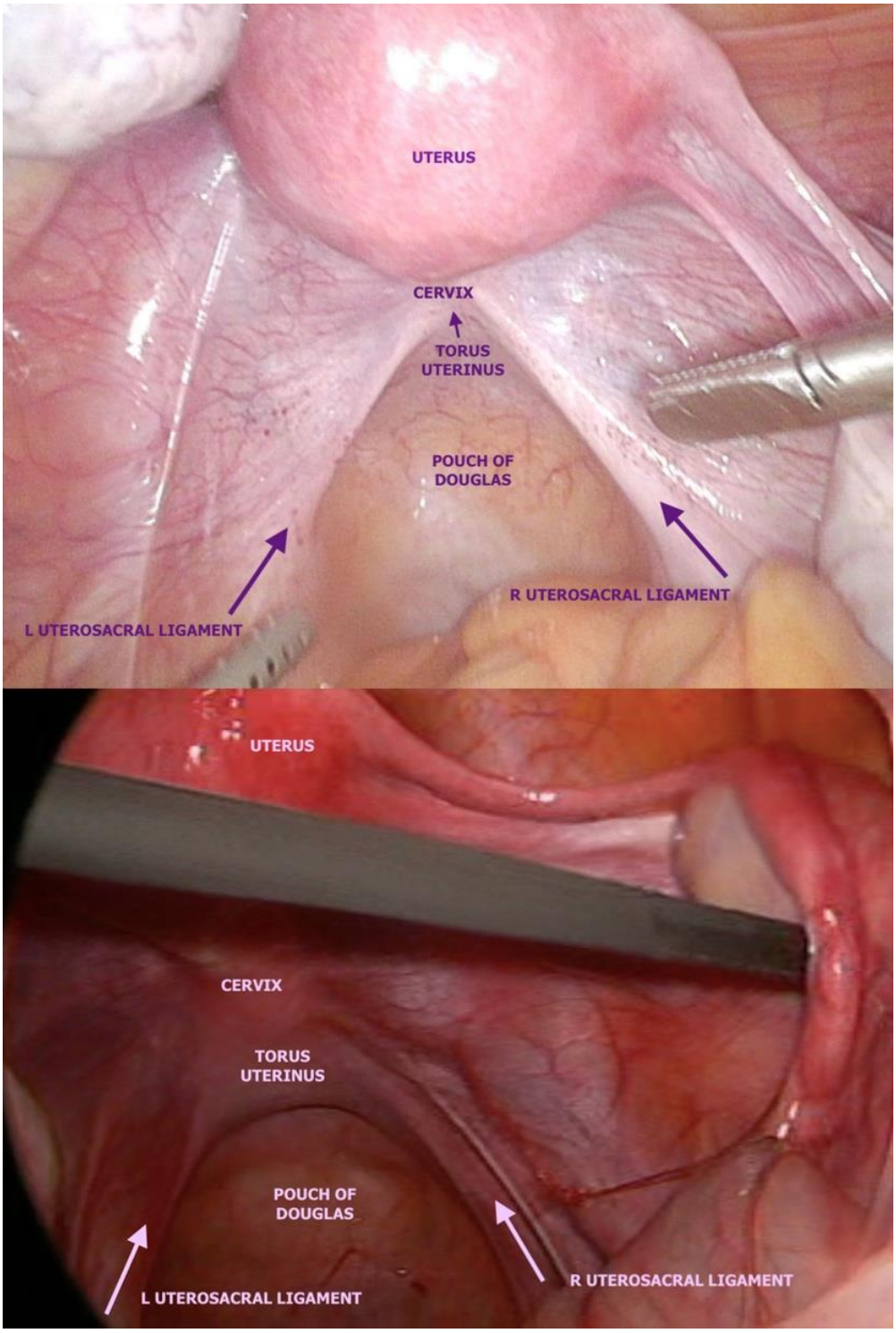


FIGURE 10. Laparoscopic Photographs Depicting Normal Pelvic Anatomy. Key: (L) Left; (R) right; (USL) Uterosacral Ligament. (Leonardi et al, 2019).[25]

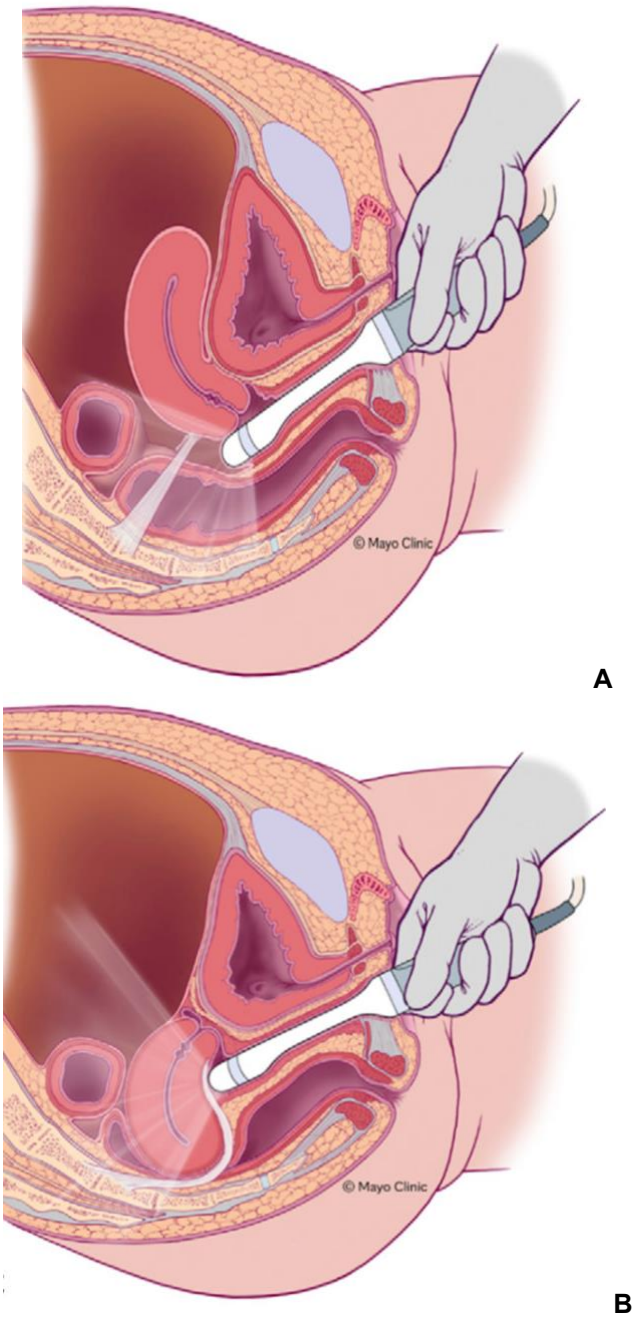


FIGURE 11. Illustration showing how to position the transvaginal sonography transducer to assess the uterosacral ligaments based on an **(A)** anteverted uterus, posterior fornix transducer position and **(B)** retroverted uterus, posterior fornix transducer position (Young 2024).[21]

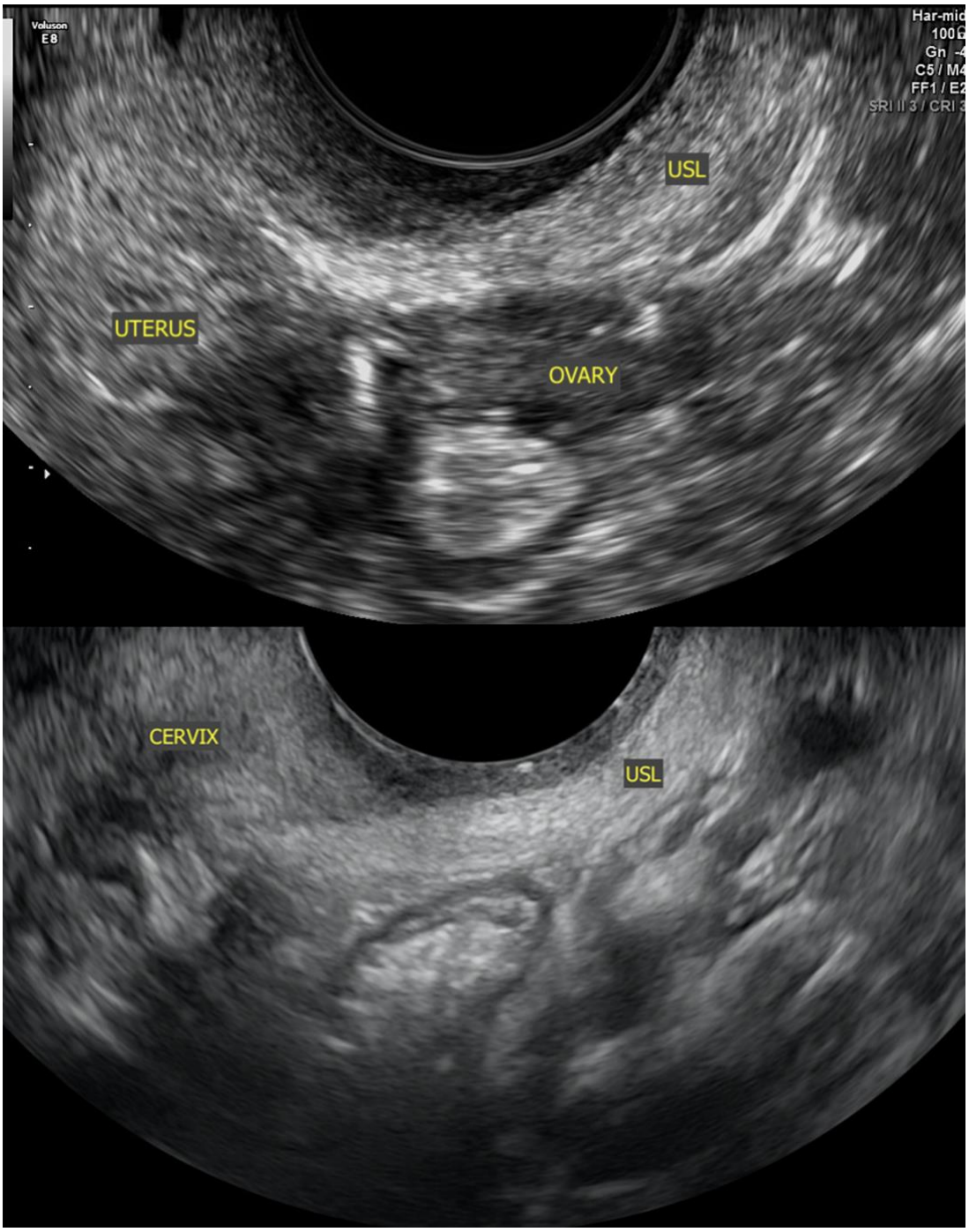
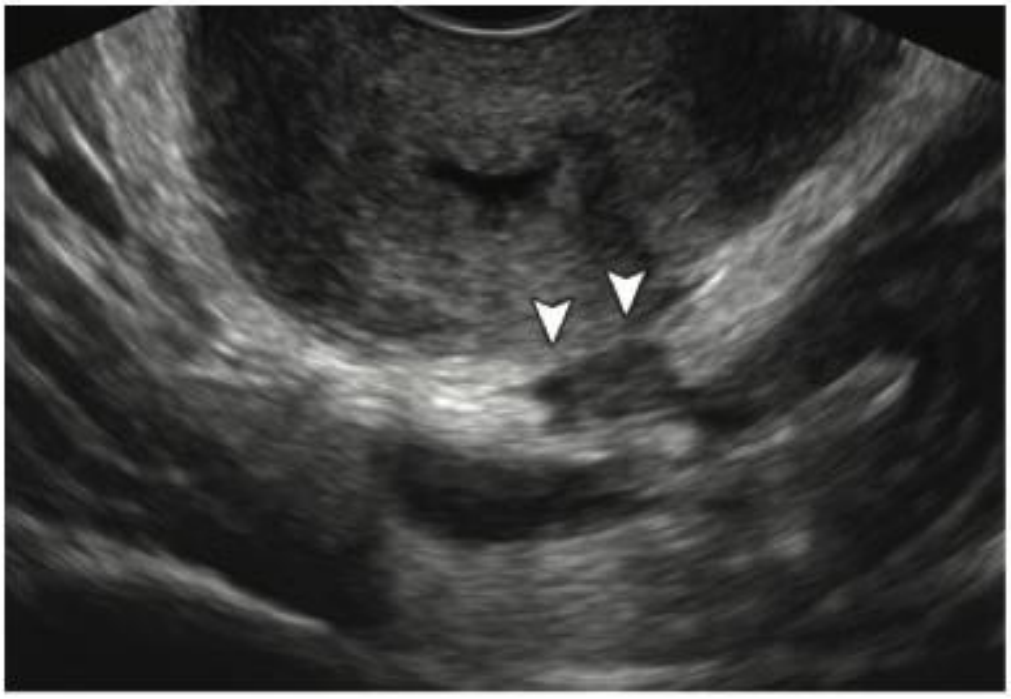
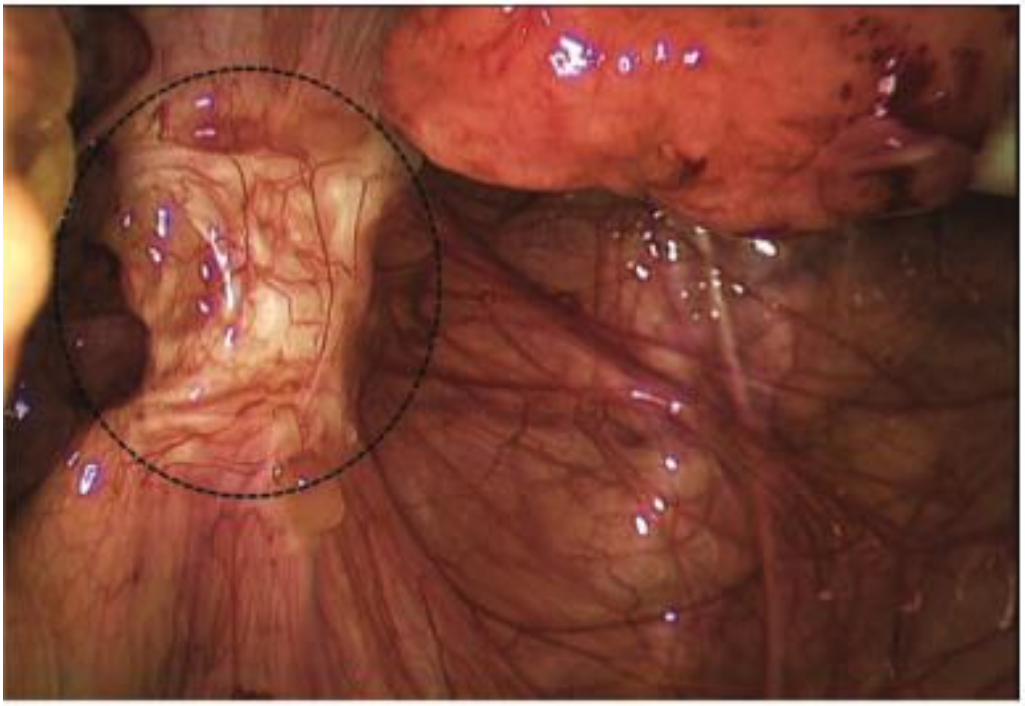


FIGURE 12. Sonographic images depicting normal anatomy of a USL, represented by the hyperechoic band of tissue close in proximity to the TVS probe.
Key: (TVS) Transvaginal Ultrasound; (USL) Uterosacral Ligament (Leonardi et al, 2019).[25]



a.



b.

FIGURE 13. Endometriosis of the USLs in a 26-year-old woman. **(a)** Axial transvaginal US image shows a small hypoechoic nodule (arrowheads) near the insertion of the left uterosacral ligament. **(b)** Laparoscopic view depicts focal infiltration and retraction of the left uterosacral ligament (dashed oval). (Chamié et al, 2022).[35]

1.2.4 Site-Specific Tenderness of USLs on Transvaginal Ultrasound

The USLs are frequently implicated in pelvic pain and disorders such as endometriosis and are strongly associated with severe pelvic pain, particularly during menstruation, sexual intercourse, or bowel movements[66]. Site-specific tenderness (SST) of the USLs is a clinical indicator of potential underlying endometriosis. During TVS, tenderness or pain elicited by palpation of the USLs may raise suspicion for endometriosis or other pelvic conditions.

Tenderness-directed scanning has been identified as a valuable component of ultrasound assessment[67]. Incorporating SST into the examination can show improved diagnostic accuracy[42]; however, it is not routinely incorporated in TVS scans. Young et al. (2017) emphasised the importance of coaching patients before the scan, explaining that reproducing pain symptoms could aid diagnosis, which improved patient compliance[67]. The IDEA[22] guidelines also recommend assessing "soft markers," including SST over the USLs (Table 3), as part of a comprehensive approach to diagnosing and managing endometriosis.

1.3 Research Problem

Patients with endometriosis often experience significant delays in diagnosis, with substantial time between symptom onset and disease confirmation. This delay is primarily due to barriers such as a lack of awareness among patients and healthcare providers, difficulties in articulating symptoms, and dismissive attitudes or misdiagnoses[26] as well as the persistent belief that surgery is the only reliable diagnostic method for endometriosis[25] (Figure 1 and Table 2). Additionally, the variability and overlap of symptoms with other conditions further complicates and prolongs diagnosis[3].

Advancements in ultrasound imaging have improved diagnostic accuracy, enabling better surgical planning and care[56]. For example, ultrasound can assist in overcoming challenges during laparoscopy, such as visualising DE of the USLs when the pouch of Douglas is completely obliterated[25]. However, most available data are derived from specialised endometriosis centres with a high prevalence of the disease, and the diagnostic accuracy of TVS for endometriosis in general imaging settings has not been investigated.

Despite these limitations, TVS is now recommended as a first-line diagnostic tool for endometriosis[7]. Therefore, it is important for all sonographers, particularly those in general imaging, to develop proficiency in this area to help reduce diagnostic delays. While advancements in TVS techniques for detecting endometriosis have progressed, fewer resources are available for USL assessment.

As USLs are often the first and most common sites for DE deposits[43], and pelvic pain is a frequent reason for requesting ultrasound, there is a need for more available resources on scanning techniques and characteristics for sonographers so they can confidently identify and diagnose any endometriotic involvement of USLs. The IDEA[22] group's 2016 guidelines provide a framework for assessing USLs. These include features like hypoechoic thickening and irregular margins for diagnosing USL DE. However, the guidelines lack standardisation, such as defining normal USL thickness or a reproducible anatomical plane for measurement.

Furthermore, while no studies directly correlate pain with USL changes in diagnosing DE, Guerriero et al. (2008) investigated tenderness-guided TVS for locating DE[42]. They found that incorporating site-specific tenderness improved specificity (94%) but achieved lower sensitivity (50%) for detecting USL DE. Limitations of their study included a small sample size and the typically small size of USL lesions[42].

While acceptable diagnostic accuracy was reported for USL evaluation, studies were largely conducted in specialist centres with experienced operators, limiting applicability to general sonographer-led ultrasound clinics.

1.4 Statement of Aims

The aims of this research are:

AIM 1	To identify ultrasound techniques and characteristics of normal and abnormal USLs in the diagnosis of endometriosis in the literature.
AIM 2	To examine the intra and interobserver agreement and reliability of TVS ultrasound characteristics of normal and abnormal USLs, including echogenicity, thickness, and nodules, between experienced and less experienced examiners in a general ultrasound imaging practice.
AIM 3	To determine a correlation and agreement between USL DE and the thickness of USLs on TVS.
AIM 4	To evaluate patient pain descriptors in the ultrasound diagnostic evaluation of endometriosis of the uterosacral ligaments, including the correlation between USL thickness and SST.
AIM 5	To investigate if the addition of patient SST pain score information alters the diagnostic decision of sonographers and radiologists when diagnosing endometriosis on TVS.

1.5 Research Process

The research presented was conducted in 3 research studies as shown in Figure 14:

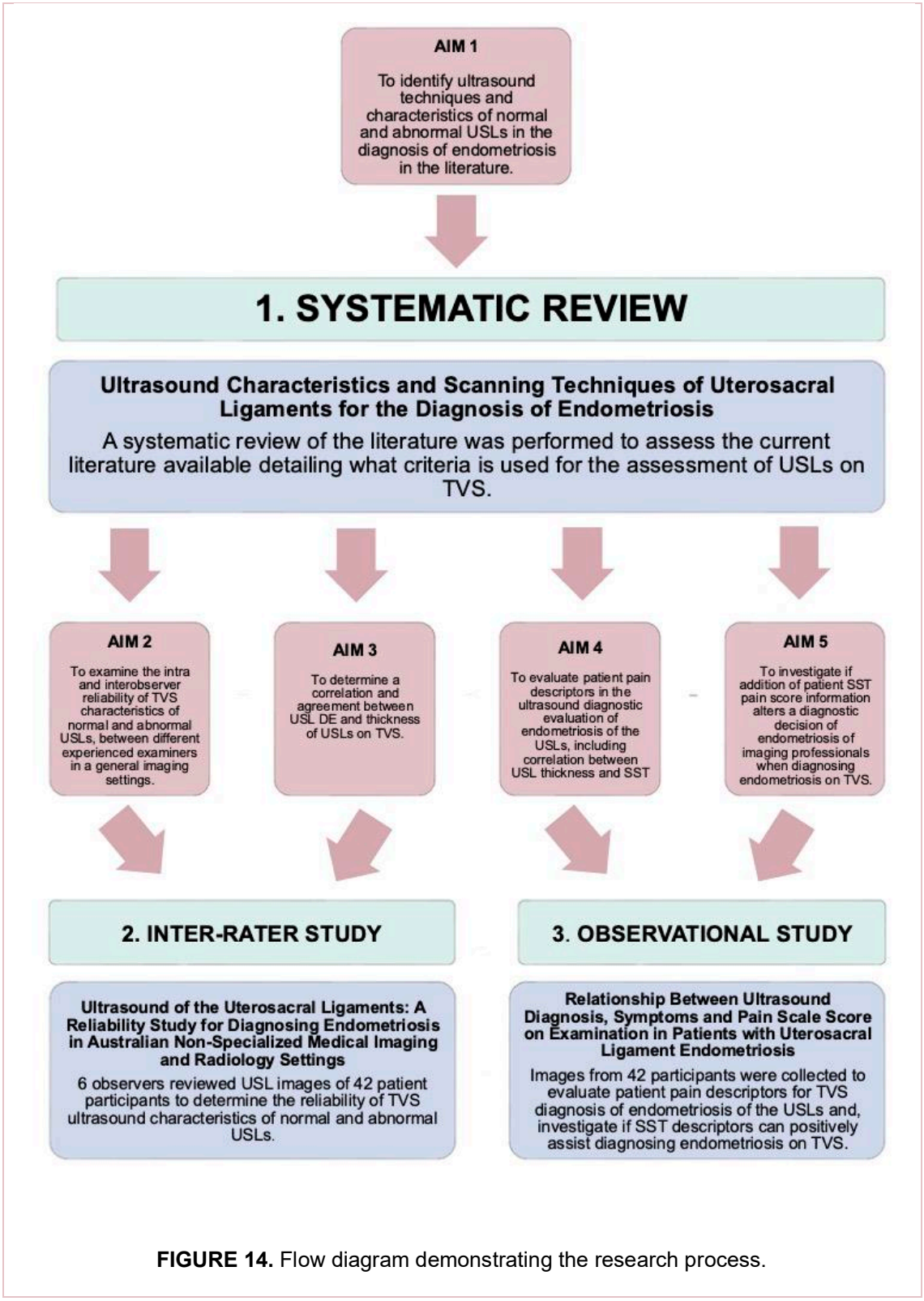


FIGURE 14. Flow diagram demonstrating the research process.

1.6 Significance of the Research

This thesis is the first to investigate the ultrasound assessment of USLs in conjunction with pain descriptors. It also pioneers the evaluation of intra and interobserver agreement and reliability of TVS characteristics of USLs in predicting endometriosis, testing the applicability of the IDEA consensus in general, non-specialist settings.

Although TVS is advancing as a non-invasive diagnostic tool for endometriosis, there are limited resources detailing the ultrasound criteria for USLs, both in normal anatomy and in the presence of DE. Existing studies have been conducted exclusively in specialist centres, which limits their applicability in general imaging settings, where sonographers may lack specialist experience or access to endometriosis-trained sonologists.

The findings from this research aim to bridge this gap by collating and testing diagnostic techniques and criteria in general imaging clinics without endometriosis specialists. It will also explore the potential diagnostic potential of incorporating pain scale descriptors into TVS assessments for DE.

The research will evaluate the feasibility of integrating USL assessment into routine pelvic ultrasound scans. Standardising these techniques and criteria is essential for consistent USL characterisation and measurement, ensuring reproducibility in general settings. Validating these protocols would lead to earlier, more accurate, and consistent diagnoses, ultimately improving patient outcomes.

1.7 Outline of the Thesis

This thesis focuses on endometriosis, a gynaecological condition affecting women and individuals assigned female at birth. While conducting this research, we acknowledge that members of the transgender and non-binary communities may also experience endometriosis. Efforts have been made to use inclusive and neutral language. Where the term “woman” is used, it encompasses all individuals with a uterus, aiming to include everyone affected by this condition.

Chapter 2 begins with a systematic review of the literature. A comprehensive review was conducted in March 2022, with the findings published in the *Journal of Ultrasound in Medicine* in November 2022, in the article *“Ultrasound of the Uterosacral Ligaments: An Intra- and Interobserver Reliability Study of Ultrasound Characteristics for the Diagnosis of Endometriosis”* (Maple et al., 2023)[68]. This publication serves as the

foundation for Chapter 2. An updated search was performed in November 2024 and the most recent findings have also been incorporated which is detailed in section 2.4 of this thesis.

The summary of the current literature leads into Chapter 3, which evaluates the reliability of diagnostic criteria among six professional observers (sonographers and radiologists) with varying levels of experience in general imaging settings. The methodology, results, and conclusions are presented in a manuscript accepted for publication by the *Australasian Journal of Ultrasound in Medicine* in December 2024. The final publication is currently undergoing proofing and will be published as *"Ultrasound of the Uterosacral Ligaments: A Reliability Study for Diagnosing Endometriosis in Australian Non-Specialised Medical Imaging and Radiology Settings"* (Maple et al., 2025)[69]. This chapter discusses the study's findings on interobserver reliability for diagnosing USL endometriosis.

Chapter 4 explores the diagnostic value of patient-reported pain descriptors during ultrasound evaluations for USL endometriosis, including the correlation between USL thickness and SST. This study investigates whether SST pain scores can enhance the accuracy of diagnosing endometriosis using TVS. The findings were published by the *Journal of Clinical Medicine* in November 2024 in the article "*Relationship Between Ultrasound Diagnosis, Symptoms, and Pain Scale Score on Examination in Patients with Uterosacral Ligament Endometriosis"* (Maple et al., 2024)[70] and are incorporated into the thesis.

All publications included in this thesis have undergone peer review. Chapter 5 concludes the thesis with a discussion of the results, clinical recommendations, applications, limitations, future research directions, novel findings and final conclusions.

Chapter 2

Ultrasound Characteristics and Scanning Techniques of Uterosacral Ligaments for the Diagnosis of Endometriosis: A Systematic Review

The published article (Maple et al., 2023)[68] forms the basis of this chapter.

Maple, S., Chalmers, K.J., Bezak, E., Henry, K. and Parange, N. (2023), ***Ultrasound Characteristics and Scanning Techniques of Uterosacral Ligaments for the Diagnosis of Endometriosis.*** J Ultrasound Med, 42: 1193-1209. https://doi.org/10.1002/jum.16129

2.1 Introduction and Motivation

This thesis aims to identify ultrasound techniques and criteria for distinguishing normal and abnormal USLs in diagnosing endometriosis. It also evaluates the intra and interobserver reliability of these criteria when applied by experienced and less experienced examiners in general ultrasound imaging settings.

In Australian general medical imaging departments, TVS examinations are performed by sonographers, who are allied health professionals with postgraduate qualifications trained to conduct ultrasound scans. Sonographers produce still images and video clips that are

subsequently reviewed and reported by radiologists. Examining for endometriosis extends beyond routine TVS protocols, requiring an evaluation of the uterus, ovaries, and adnexa, alongside additional steps outlined in the International Deep Endometriosis Analysis (IDEA)[22] consensus, particularly the sliding sign and posterior compartment assessment where the USLs are located. These advanced techniques have traditionally been implemented in specialist centres by highly trained sonologists and gynaecologists, only recently making their way into general settings[36]. This shift requires a learning curve for both sonographers and radiologists.

Given the high prevalence of pelvic pain referrals for TVS, equipping sonographers with the skills to perform these examinations at a high standard is critical to reducing diagnostic delays for endometriosis. To address this, a systematic review was conducted to evaluate the existing literature and build upon the IDEA[22] consensus to provide clearer criteria for TVS scanning of USLs. Insights from this review were used to develop criteria for identifying normal and abnormal USLs, formulate research questions, and design the studies 2 and 3 presented in this thesis[68].

2.2 Published Journal Article

Pages 51-67 contain the research paper by Maple et al., (2023)[68] as published in *The Journal of Ultrasound in Medicine (JUM)*, November 2022.

Ultrasound Characteristics and Scanning Techniques of Uterosacral Ligaments for the Diagnosis of Endometriosis

A Systematic Review

Shae Maple, B.MedRad, G.DipMedSon, K Jane Chalmers, B.Physio, PhD, Eva Bezak, PhD, Katelyn Henry, B.Physio, Nayana Parange, MBBS, MS, PhD

Received August 2, 2022, from the Allied Health and Human Performance, University of South Australia, GPO Box 2471, Adelaide, SA 5001, Australia (S.M., K.J.C., E.B., K.H., N.P.). Manuscript accepted for publication October 30, 2022.

This review is supported by the University of South Australia. No funding bodies played any role in developing this review.

The authors declare no conflict of interest.

Address correspondence to Shae Maple, Allied Health and Human Performance, University of South Australia, GPO Box 2471, Adelaide, SA 5001, Australia.

E-mail: shae.maple@mymail.unisa.edu.au

Abbreviations

CASP, Critical Appraisal Skills Programme; DE, deep infiltrative endometriosis; IDEA, International Deep Endometriosis Analysis; LUSL, left uterosacral ligament; MRI, magnetic resonance imaging; POD, pouch of Douglas; RES, rectal endoscopic sonography; RUSL, right uterosacral ligament; RWC-TVS, rectal water-contrast transvaginal ultrasound; SVG, sonovaginography; TRUS, transrectal ultrasound; TVS, transvaginal ultrasound; USLs, uterosacral ligaments

doi:10.1002/jum.16129

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

Endometriosis is a common and painful gynaecological condition that takes an average of 6.4years to diagnose. While laparoscopic surgery is the recommend gold standard in diagnosis of endometriosis, transvaginal ultrasound (TVS) is able to assist surgeons in the planning and management of patients, especially when there is limited visualisation in the posterior compartment. Uterosacral ligaments (USL) are located in the posterior compartment and are one of the first and most common places that endometriosis deposits, The International Deep Endometriosis Analysis (IDEA) group consensus, which are the current guidelines for DE imaging, recommends a thorough ultrasound assessment to identify endometriotic disease. This includes an assessment of anatomic structures in the posterior compartment including the USLs. However, IDEA does not explicitly articulate specifics of USL imaging and measurements on ultrasound. The primary aim of this review is to determine is to identify ultrasound techniques and characteristics of USLs in the diagnosis of deep infiltrative endometriosis (DE). The secondary aim is to describe and summarise these findings into normal and pathological findings. A systematic review was performed according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A population, interventions, comparator, and outcome framework was used to define a search strategy. Articles were screened using Covidence review management system, and data was extracted by two authors using a standardised and piolet-tested form. Quality assessment was conducted using the Critical Appraisal Skills Programme (CASP). Medline, Embase and Scopus and Google Scholar were searched yielding 250 articles, with 22 being included in the review. Analysis of the data demonstrated inconsistent reporting of ultrasound techniques and characteristics of USLs. Most (20/22) papers described abnormal criteria of USLs, only 5/22 papers determined what the normal USL appearance is or what techniques (11/22) were applied. Even though reporting was heterogeneous, there was a high level of tertiary centre participation with gynaecological experienced operators, therefore was a high level of agreement. Through review of the current literature, this study has investigated ultrasound techniques and characteristics of USLs for the diagnosis of DE. All papers included in this review reported presence of pathological sonographic findings of the USLs when DE was presented therefore it is recommended that USL examination become a part of TVS exams when DE is clinically suspected. This study also demonstrated that there was lack of data and no agreement when it comes to measuring USLs with DE. Even so, the current evidence demonstrates that scanning the USLs, and locating, identifying, and describing USL thickening and endometriotic nodules in the various locations using the described techniques and characteristics in this review has clinical value in early diagnosis.

Key Words—deep infiltrating endometriosis; gynecology; sonographer; transvaginal ultrasound; uterosacral ligaments

© 2022 The Authors. *Journal of Ultrasound in Medicine* published by Wiley Periodicals LLC on behalf of American Institute of Ultrasound in Medicine.

15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Endometriosis is a common and painful gynecological condition that is characterized by the presence of endometrial-like tissue extending outside of the uterine cavity.[1] Endometriosis affects 10% of women of reproductive age[2] and is associated with a wide range of symptoms, including menstrual pain, chronic pelvic pain, and infertility.[3,4] Patients with endometriosis face an average 6.4 years[5] of delay in diagnosis.

When endometriotic lesions extend into the peritoneum with infiltration of the tissue deeper than 5 mm,[6,7] deep infiltrative endometriosis (DE) is diagnosed.[8] Clinical practice guidelines recommend that laparoscopy with histological confirmation is the current the gold standard for diagnosis of endometriosis.[8 10] However, there are limitations of laparoscopic surgery to diagnose endometriosis such as poor visualization of the posterior compartment when there is complete obliteration of the pouch of Douglas (POD).[4,11] Often the surgical procedure in these cases is complex requiring specific advanced operative skills[12,13] due to the extensive dissection and higher risk of surgical injury.[11]

More recently, transvaginal ultrasound (TVS) has been used prior to laparoscopic surgery to improve the standard of surgical planning and care.[7,11,14] Some benefits of using TVS include providing information as to what to expect at surgery,[12] offering pre surgical counselling, treatment options and, information of risks and benefits to surgery. In particular, the role of TVS in pre surgical planning may reduce the need for an advanced skilled second laparoscopy especially where endometriotic nodules are found adhered to bowel or bladder and a multidisciplinary surgical team is required in these complex cases.[12] In severe cases, TVS can assist gynecological surgeons in visualizing anatomy in the posterior compartment in the presence of DE and POD obliteration.[4] Overall, the accuracy of TVS in diagnosing DE is high ranging from 75.7 to 97%[15] with sensitivities of 78.5 to 85.3%, and specificities of 46.1 to 92.5%.[15]

Uterosacral ligaments (USLs) are one of the first and most common places that DE deposits.[1,3,4,7,8,14 18] USLs are located in the posterior compartment[3] and are a leading cause of deep dyspareunia and pelvic pain[3] in people with endometriosis. Chapron et al[17] conducted a large observational study with surgical and histological results reporting that 69.2% of patients with DE have USL DE while Fratelli et al[19] reported disease affecting the USLs in 61% of their participants on laparoscopy.

Although the overall accuracy of TVS in diagnosing DE is high, its role in diagnosing DE specifically of the USLs is less clear. Meta-analysis for detection of USL endometriosis has demonstrated an overall pooled sensitivity of 60 and 95% specificity.[20] One explanation for this is the lack of validated criteria available for ultrasound diagnosis of USL DE. The 2016 International Deep Endometriosis Analysis (IDEA) group[18] guidelines outline some features that can be used to diagnose USL DE, such as hypoechoic thickening and irregular contour of margins as well as site-specific tenderness (SST) over the USLs. Regarding measuring the USLs, the IDEA[18] consensus recommends measuring transversely at the insertion of the ligament on the cervix. However, a limitation of the IDEA[18] guidelines is that the normal thickness of USLs is currently unknown and the standard anatomic plane for reproducible measurements for USLs is not included. To accurately and reliably diagnose USL DE, these factors need to be determined and described.

Therefore, the aim of this systematic review was to identify and synthesize data of ultrasound techniques and characteristics of USLs in the diagnosis of endometriosis. The secondary objective was to describe and summarize the ultrasound imaging methods of USLs and collectively assess the normal and pathological ultrasound characteristics.

Methods

Study Design

This systematic review was performed according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses[21] statement. All methods for inclusion/exclusion criteria, data extraction, and quality assessment were specified in the developed protocol for systematic review prior to commencement. The protocol was prospectively registered on PROSPERO (ID.267833) on August 14, 2021 and on Open Science Framework (https://osf.io/n7cxs/) on July 14, 2021.

15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Eligibility Criteria

A population, intervention, comparator, and outcome framework was used to define the research question and strategy. A search strategy was developed to identify ultrasound techniques and characteristics of USLs in the diagnosis of endometriosis using medical subject headings and key words relating to "endometriosis," "uterosacral ligament," and "ultrasound."

The inclusion criteria used for this review were as follows: 1) studies including women of reproductive age with clinically diagnosed with endometriosis; 2) ultrasound of endometriosis of USLs performed or described; 3) reports of ultrasound characteristics and technique for imaging of endometriosis of USLs were mentioned; 4) published, peer-reviewed journal articles. The exclusion criteria were 1) non-English studies; 2) secondary data (eg, reviews); 3) animal or in vitro studies; or 4) studies published prior to the year 2000. The date restriction was a deviation from the protocol and was applied as the review team deemed that techniques applied prior to this date would be outdated and not reflect current clinical practice.

Information Sources

Three electronic databases (MEDLINE, Embase, and Scopus) were selected to identify eligible studies. Additional searches and screening were performed to identify eligible articles, including through Google Scholar (first 100 references), connected papers (https://www.connectedpapers.com), reference lists of previous reviews, reference lists of endometriosis guidelines, and reference lists of included articles.

Search

Studies identified from the electronic database search were exported into EndNote (version 20.2, Clarivate, Philadelphia, USA) and screened for eligibility as per the inclusion criteria using Covidence[22] systematic review software (Veritas Health Innovation, Melbourne, Australia). All title and abstract screening (SM and NP) and full-text screening (SM and KJC) were completed independently by 2 reviewers and in compliance with the inclusion and exclusion criteria. Any discrepancies or disagreements between the 2 reviewers were discussed. If a disagreement was not resolved through this process, a third reviewer

Table 1. Critical Appraisal Skills Programme (CASP) Summary, by Criterion for Quality Assessment Evaluation for a Diagnostic Test Study for All 22 Included Studies

		Quality Assessment of Studies		
Criteria	**Question**	**Met Criterion**	**Can't Tell**	**Did Not Meet**
Section A	**Are the results of the study valid?**			
Aim	Was there a clear question for the study to address?	22	0	0
Reference Standard	Was there a comparison with an appropriate reference standard?	20	0	2
Procedures	Did all patients get the diagnostic test and reference standard?	17	0	5
Bias	Could the results of the test have been influenced by the results of the reference standard?	14	7	1
Study design	Is the disease status of the tested population clearly described?	20	2	0
Methods	Were the methods for performing the test described in sufficient detail?	21	0	1
Section B	**What are the results?**			
Results	What are the results?	22	0	0
Data analysis	How sure are we about the results? Consequences and cost of alternatives performed?	6	16	0
Section C	**Will the results help locally?**			
Findings	Can the results be applied to your patients/the population	5	3	14
Current practice	Can the test be applied to your patient or population of interest?	5	5	12
Value of study	Were all outcomes important to the individual or population considered?	20	2	0

15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

(EB) provided opinion and a majority decision was made.

Data Collection

Data were extracted from multiple sources that specifically detailed ultrasound technique and characteristics of USLs. To establish ultrasound technique, a description of ultrasound approach was extracted, including information on transducer position and/or angulation, scan plane, and image optimization. To determine ultrasound characteristics, a description of what criteria was used to determine ultrasound characteristics of normal and/or abnormal USLs was collected. In addition, any description of measuring USLs including numerical limits was also collected.

Two authors (SM and KH) independently extracted relevant data using a standardized and pilot-tested form. Each article was read systematically, and relevant data were extracted into individual excel spreadsheets. The data were then cross checked by NP and EB for accuracy and presented to all authors for analysis and discussion.

Risk of Bias in Individuals

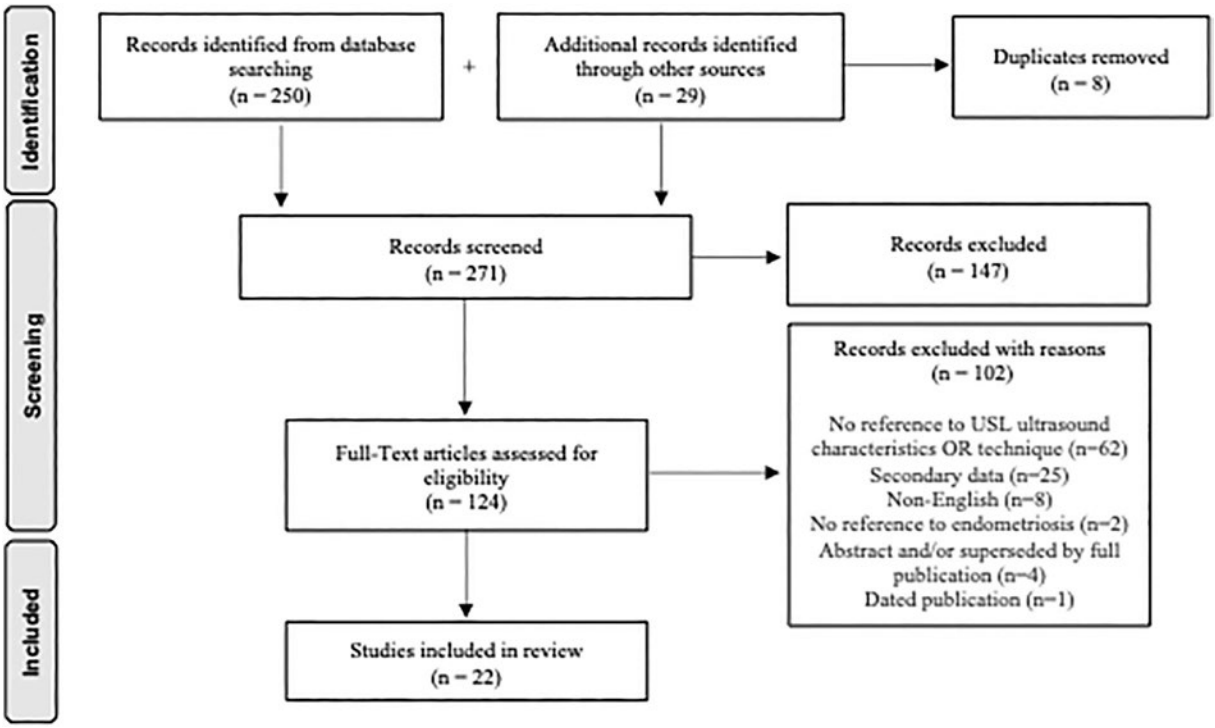
Quality assessment was conducted using the Critical Appraisal Skills Programme (CASP)[23] where the risk of bias and applicability was analyzed and recorded as a "yes," "no," or "cannot tell." Two authors (SM and NP) independently evaluated risk of bias using an Excel (Microsoft Corporation, 2018) spreadsheet based on the standard form with quality assessment criteria. Any disagreements were resolved by discussion.

Results

Database Search and Risk of Bias Assessment

The initial database search resulted in 250 articles; 8 duplicates were removed. A further 29 articles were found through the additional search processes.

Figure 1. Flow of studies as modelled by the Preferred Reporting Items for Systematic Review and Meta-Analysis outlining the studies identified in the literature for systematic review on ultrasound characteristics and scanning techniques of uterosacral ligaments for the diagnosis of endometriosis.



15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Table 2. Data Spread of Reviewed Papers Covering USL Characteristics

Article	Date	Study Design	Approach	Bowel Preparation	Ultrasound Technique	Measurement Technique	Normal USL Characteristics	Abnormal USL Characteristics	SST
Abrao et al	2007	Cross-sectional Study	TVS	Y	–	–	–	√	–
Barra et al	2021	Prospective	TVS/RWC-TVS/SVG	Y	–	–	–	√	–
Bazot et al	2009	Retrospective Longitudinal	TVS	N	–	–	–	√	–
Bazot et al	2007	Longitudinal	TVS/RES	N	√	√	–	√	–
Bazot et al	2004	Prospective	TVS	N	√	√	√[a]	√	–
Bratila et al	2016	Prospective	TVS/SVG	NS	√	–	–	√	–
Chowdary et al	2019	Retrospective	TVS	Y	√	√	–	–	√
El-Maadawy et al	2021	Prospective Observational	TVS/TRUS	N	–	–	–	√	√
Grasso et al	2010	NS	TVS (3D)	N	–	–	–	√	–
Guerriero et al	2018	Prospective Observational	TVS (2D + 3D)	NS	–	–	–	√	√
Guerriero et al	2014	Diagnostic Test Study	TVS (2D + 3D)	NS	√	√	–	√	√
Holland et al	2013	Prospective Observational	TVS	NS	–	–	–	√	–
Hudelist et al	2011	Prospective Diagnostic	TVS	N	√	–	–	√	–
Hudelist et al	2009	Prospective	TVS	N	√	–	–	√	–
Lima et al	2017	Cross-sectional Observational	TVS MRI fusion	Y	–	√	–	–	–
Millischer et al	2015	Prospective	TVS	N	–	–	√	√	–
Robinson et al	2018	Prospective Observational	TVS	N	√	√	√	√	√
Ros et al	2021	Prospective Diagnostic	TVS	Y	√	–	–	√	–
Vimercati et al	2012	Prospective Diagnostic	TVS	N	–	–	–	√	–
Yin et al	2020	Retrospective	TVS	NS	–	–	√	√	√
Young et al	2017	Retrospective	TVS	Y	√	–	–	√	√
Zhang et al	2019	Prospective	TVS	NS	√	√	√[b]	√	√

MRI, magnetic resonance imaging; N, no; NS, not specified; RES, rectal endoscopic sonography; RWC-TVS, rectal water-contrast transvaginal ultrasonography; SVG, sonovaginography; TRUS, transrectal ultrasound; TVS, transvaginal sonography; Y, yes.

[a]Referenced from another paper.

[b]In discussion.

15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Following screening, 22 articles were included in the review. The CASP[23] guidelines were used to assess methodological quality as shown in Table 1. The full screening process can be found in Figure 1.

Study Characteristics

All of the 22 included studies described ultrasound technique and/or characteristic criteria of USLs. Table 2 summaries these data spread across all articles. The included articles were published between 2004 and 2021. Table 3 shows that 13 of the studies specified that they were from tertiary centers, while the remaining 9 did not specify. Operators of all studies were shown to have significant experience as gynecology surgeons, sonologists, or radiologists. In 3 studies, sonographers were used who had experience[24,25] in diagnosing endometriosis.[26]

Study Findings

Collectively, the data show inconsistent reporting of ultrasound technique and characteristic criteria of

Table 3. TVS Operator Qualifications, Experience, and Ultrasound Setting

Article	Date	Tertiary Center	Operators	Operator Qualifications	Operator Experience
Abrao et al	2007	NS	1	Radiologist	NS
Barra et al	2021	NS	2	Gynecological sonologist	Extensive experience in diagnosing DE (over 500 transvaginal sonograms for DE).
Bazot et al	2009	Y	1	Radiologist	NS
Bazot et al	2007	Y	1	Radiologist	Extensive gynecological experience.
Bazot et al	2004	NS	1	Radiologist	More than 10 years of experience with TVS at the onset of the study
Bratila et al	2016	NS	2	Sonographers	Experienced in diagnosing endometriosis
Chowdary et al	2019	Y	1	Gynecological Sonologist	Expertise in endometriosis assessments
El-Maadawy et al	2021	Y	2	Radiologist	Highly experienced in the field of women imaging particularly TVS assessment of DE
Grasso et al	2010	NS	1	Gynecologist	20 years of experience of endometriosis and gynecologic ultrasound
Guerriero et al	2018	Y	1	NS	23 years of experience in gynecologic ultrasound
Guerriero et al	2014	Y	1	NS	>20 years of experience in gynecological ultrasound
Holland et al	2013	Y	2	Gynecologists	High level of expertise in gynecological ultrasonography
Hudelist et al	2011	Y	1	Gynecologist	NS
Hudelist et al	2009	Y	3	Gynecologists	Extensive >5 years of experience in TVS for DE
Lima et al	2017	Y	1	Radiologist	NS
Millischer et al	2015	NS	1	Radiologist	High level of expertise in gynecological ultrasonography (7 years of referral practice and a mean of 1800 scans/year)
Robinson et al	2018	Y	1	Gynecological Sonologist	>4 years of experience with ultrasound diagnosis of DE at the onset of the study
Ros et al	2021	Y	2	Sonographers	Experienced sonographers
Vimercati et al	2012	NS	1	Sonographers	Expert sonographer >10 years of experience
Yin et al	2020	NS	1	NS	Examiner who had received professional training
Young et al	2017	Y	1	Radiologist	5 days of observational training in the ultrasound diagnosis of DE under the instruction of expert radiologists in a high-volume referral center for endometriosis. Technical assistance to the performing radiologist, including patient positioning, annotation, and image optimization, was provided by a registered diagnostic medical sonographer.
Zhang et al	2019	NS	1	NS	Examiner who had received professional training

DE, deep infiltrative endometriosis; N, no; NS, not specified; TVS, transvaginal ultrasound; Y, yes.

15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

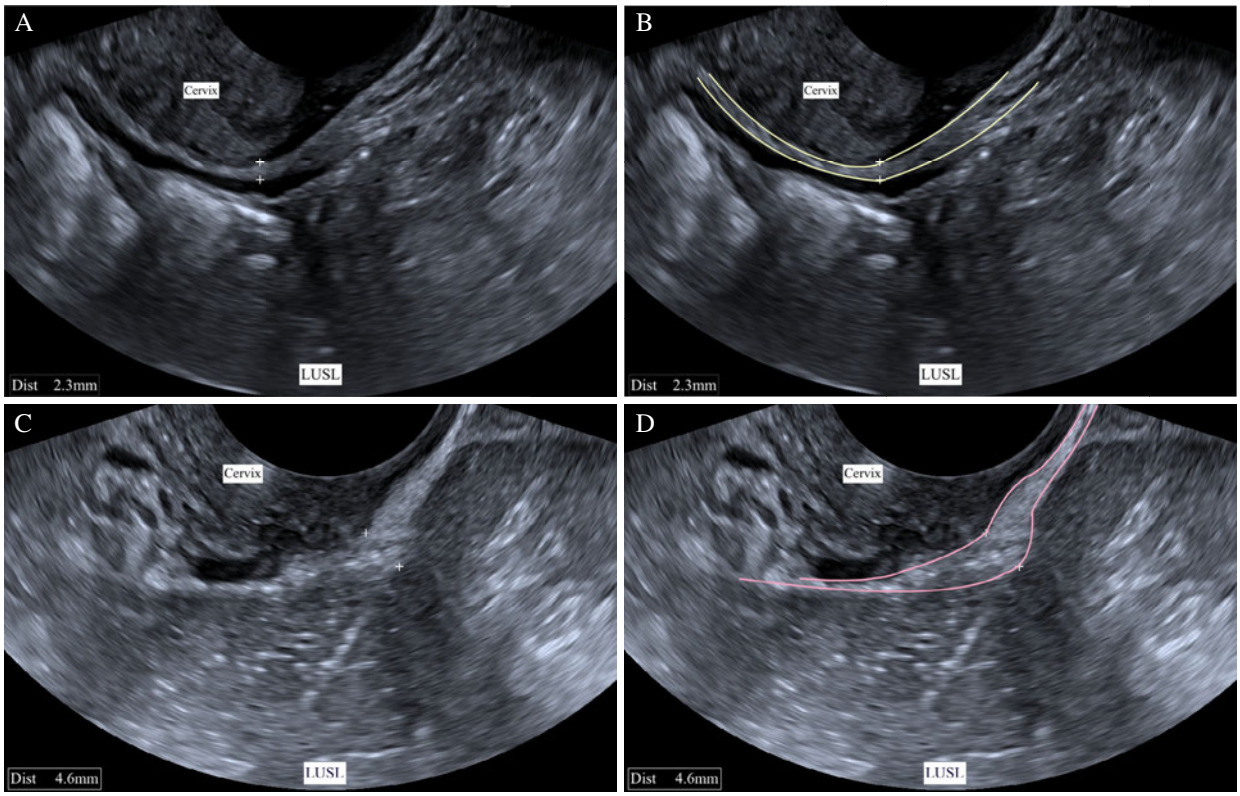
USLs as demonstrated in Table 2. Results showed that while the included papers demonstrated at least one of the inclusion criteria, only 3 of 22 papers[1,27,28] described all 3 of our inclusion criteria: ultrasound technique, normal USL characteristics, and abnormal USL characteristics.

Table 4. Summary of Ultrasound Technique Data from the Included Articles as summarized from the Reviewed Papers

Ultrasound technique to visualize USLs	Ultrasound technique for abnormal USLs
1. Insert the TVS transducer into the posterior vaginal fornix[1,14,26 30,33] 2. Slowly withdrawn the transducer into the vagina to assess the visualization of the posterior compartment (ie, USLs, posterior fornix of the vagina, rectovaginal septum, and pouch of Douglas and rectosigmoid)[1,14,26,28 30,33] 3. Optimize the image[27]: The USL is close to transducer so decrease the depth for a small depth of field and position the focal point at region of USL 4. To visualize USL, keep the transducer in the longitudinal plane in the midsagittal position[27,28] angled inferolaterally to visualize the cervix/posteriorly toward the rectum.[32] 5. Slowly rotate to each side,[28,29] at approximately 45° from the midline[24,27] 6. The USL will be visualized as a hyperechoic line that begins to thicken as it comes into view[27] 7. Image the USL in sagittal section when the hyperechoic USL is thickest[27]	*Follow the same approach as normal USLs and then*: 8. Document any site-specific tenderness,[28] as directed and indicated by the patient[29] 9. Describe appearance of USL[28] 10. Measure USL thickness[1,28,32,35,39] 11. Measure any hypoechoic lesions within the hyperechoic USL in 3 orthogonal planes[18,28] 12. Evaluation of the ureters should be done for all patients found to have USL nodules[34,43]

LUSL, left uterosacral ligament; RUSL, right uterosacral ligament; TVS, transvaginal ultrasound; USL, uterosacral ligament.

Figure 2. Calliper placement for uterosacral ligament (USL) measurement. **A** and **B**, Calliper placement (+) for measurement of the USL at the proximal part, near the insertion on the cervix in the midsagittal plane. **C** and **D**, Calliper placement (+) for measurement of USL at the thickest point in the midsagittal plane.



15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Table 4 summarizes the data extracted from the 11 articles containing TVS technique to examine USLs.[1,14,24,26 33] Although there was some consensus in technique, overall technique was ill defined with each study reporting different aspects of the technique. No study provided a comprehensive approach inclusive of transducer placement or angulation, transducer pressure, image optimization, and optimal USL image and/or calliper placement for measurement. Chowdary et al[32] was the only paper to describe scanning the USL in the axial view, in contrast with Zhang et al[28] and Robinson et al[27] who described keeping the transducer in the longitudinal plane in the midsagittal position.[27,28] Other papers did not report on which plane was used.[1,14,24,26,29 31,33]

Furthermore, only 7 of the 22 included papers[1,27,28,31 34] reported on USL thickness and its usefulness (Table 2). Some degree of variable measuring techniques was demonstrated in the included papers. These can be categorized into 2 basic approaches: measure at the proximal part, near the insertion on the cervix[1,28,31,33] (Figure 2, A and B.), or measuring at the thickest point[34] (Figure 2, C and D.).

A summary of the ultrasound characteristics used for the diagnosis of USL in the reviewed articles is in Table 5. Although most papers (20/22)[1,14,16,24 31,33,35 42] described the diagnostic criteria they used for an abnormal or diseased USL, many failed to determine what the normal USL appearance is or outline what measurement techniques were applied. In total, only 5 papers[27,28,35,36] described a normal USL.

Ultrasound appearance of DE nodules associated with USLs was well documented in the included studies as a solid,[37] hypoechoic[24,25,27 29,35,37,39] lesion with regular, irregular[29] or stellate margins.[1,16,25,26,28,31,33,35 38,41] A specific finding was the positive association of USL endometriosis with ureteral endometriosis[43] where Lima et al[34] concluded that USLs with nodules that measure 1.75 cm on the right and 1.95 cm on the left significantly increase the risk of ureteral involvement.

Holland et al[37] specified that "endometriotic nodules are tender on palpation and fixed to the surrounding pelvic structures." However, results showed that most studies failed to demonstrate SST results with only 8 of 22 papers[27 29,31,32,35,38,40] referring to SST of USLs (Table 2). Of these 8 papers, tenderness-guide was used was used as a diagnostic direction tool only and was not objectively measured. There were no papers that demonstrated a pain symptom scale or reproducible reporting system of SST. Only Robinson et al[27] reported SST results where it was reported that "SST of either USL area at TVS was elicited in 49 (60%) of the 81 women." Although, "23 of 49 women with unilateral or bilateral tenderness at TVS did not have surgically confirmed endometriosis of the ipsilateral USL."

Table 5. Summary of the Ultrasound Characteristics Used for the Diagnosis of USL in the Reviewed Articles

Normal USL	USL DE Appearance	USL DE Nodule Appearance	Other Observations
Hyperechoic or homogeneous[24,27,35]	Hypoechoic interruptions or heterogeneous[24,26,28,35,41]	Hypoechoic[24,25,27 29,35,37,39] or isoechoic[37]	Butterfly configuration[40]
Homogeneous linear band[1,36]	Hypoechoic linear thickening[1,16,26,27,31,33,35,38,41]	Hyperechogenic contours, with or without hyperechogenic foci[25,31,41]	Tram-track configuration[40]
Thin USL[27]	Thickened USL[1,28,35,39]	Solid mass[37]	
<3 mm[32]	>3 mm[32]		
Smooth margins[27]	Regular or irregular margins[1,16,31,33,35,38,41]	Regular, irregular[29] or stellate margins[1,16,25,26,28,31,33,35 38,41]	
Slides freely[27]	Stiffening[28,35]	Immobility/adhesed[27,28,37]	
	Asymmetry of USLs[26]	Tender on palpation[37]	
	Bore a nodule[1,16,24 28,31,33,35,36,38,39]	No detectable colour Doppler[25]	

(DE, deep infiltrative endometriosis; USL, uterosacral ligament.

15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Discussion

This systematic review identified and evaluated data of ultrasound techniques and characteristic criteria of USLs for the diagnosis of endometriosis. Although the results were consistent in agreeing on the ultrasound technique, measurement technique, and the difference between normal and abnormal USL appearance, there was inconsistency on the detail included in the papers. One clear reason for high agreement is the high level of tertiary center participation in the reviewed ultrasound studies of endometriosis.

It is reasonable to suggest that the setting where a patient presents for recruitment influences the outcome.[44] A previous study has found that outcomes in women with endometriosis are highly influenced by recruitment strategies.[44] De Graff et al concluded that women recruited from secondary care (defined as a general hospital, not being a referral center) and women recruited from tertiary care (defined as an academic hospital or a referral center) are 2 different patient populations that are not directly comparable.[44]

This finding was unexpected and not identified in our aims, although significant as it suggests that

Table 6. Findings of the Systematic Review of Ultrasound Techniques Compared to Leonardi et al,[4] the *IDEA[18] Consensus and the Enzian Classification[47]

	Leonardi Education (2019)[4]	IDEA Consensus (2016)[18]	Enzian Classification (2021)[47]
Ultrasound technique to visualize USLs:			
1. Insert the TVS transducer into the posterior vaginal fornix[1,4,14,18,26 30,33,47]	√	√	√
2. Slowly withdrawn the transducer into the vagina to assess the visualization of the posterior compartment[1,14,26,28 30,33]	X	X	X
3. Optimize the image[27]: The USL is close to transducer so decrease the depth for a small depth of field and position the focal point at region of USL[4]	√	X	X
4. To visualize USL, keep the transducer in the longitudinal plane in the midsagittal position[4,18,27,28,47] angled inferolaterally to visualize the cervix[4,18,47]/posteriorly toward the rectum[32]	√	√	√
5. Slowly rotate to each side,[18,28,29,47] at approximately 45° from the midline[4,24,27]	√	√	√
6. The USL will be visualized as a hyperechoic line that begins to thicken as it comes into view[4,27]	√	X	X
7. Image the USL in sagittal section when the hyperechoic USL is thickest[4,27]	√	X	X
When USL is abnormal:			
8. Document any site-specific tenderness,[4,28] as directed and indicated by the patient[18,29]	√	√	X
9. Describe appearance of USL[4,18,28]	√	√	X
10. Measure USL thickness[1,18,28,32,35,39]	X	√	X
11.Measure any hypoechoic lesions within the hyperechoic USL in 3 orthogonal planes[4,18,28]	√	√	X
*11a. Identify the number and size of any USL nodules[18]	X	√	X
*11b. Describe anatomical location of any USL DE nodules including if lesion is isolated to USL or part of a larger nodule extending into the torus uterinus or surrounding structures[4,18]	√	√	X
*11c. Note the most lateral extension diameter of any USL nodule[47]	X	X	√
12. Evaluation of the ureters should be done for all patients found to have USL nodules[4,34,43]	√	X	X

*Not suggested in any of the included papers, but are recommendations made by the industry standard references.

IDEA, International Deep Endometriosis Analysis; TVS, transvaginal ultrasound; USL, uterosacral ligament; X, paper did not use this step; √, paper used this step.

15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

currently the ultrasound diagnosis of DE is more reliable within tertiary settings. Here, sonologists, who are usually gynecologists with specialized ultrasound training and advanced knowledge of endometriosis diagnosis and management,[11,45] can perform both TVS and laparoscopic surgery. Occasionally, a sonographer may perform the ultrasound, and in these cases the findings are reported by the sonologist who also consults the patient.[11] Either way, sonologists can use ultrasound as an extension of their physical exam in the diagnosis and management of endometriosis to assist their pre surgical planning.[11] It is known that TVS is a highly accurate and reproducible method for noninvasive diagnosis of DE by well-trained professionals[46]; however, the question still remains if these techniques are reproducible in general settings.

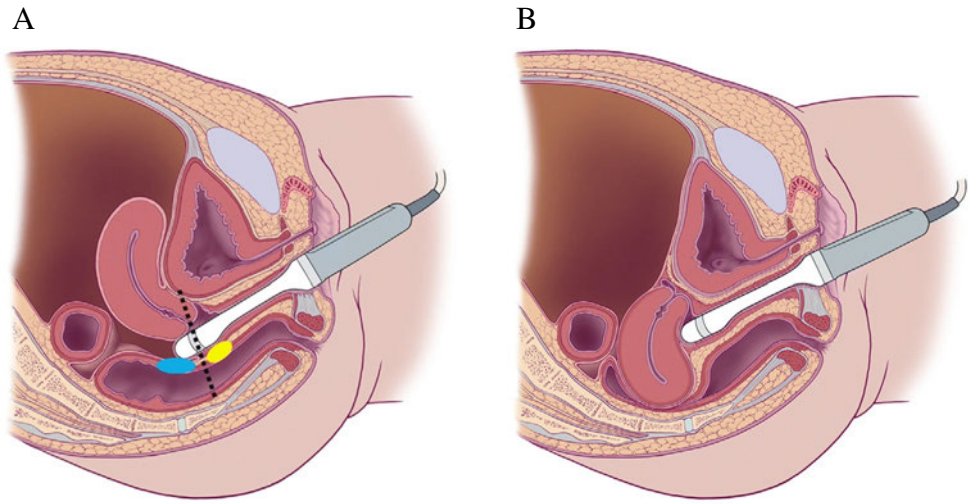
Current industry guidelines by the IDEA[18] group recommends a thorough ultrasound assessment beyond a basic scan to identify endometriotic disease. This includes a 4-step assessment of all anatomic structures including the posterior compartment and the USLs. It is also indicated that sonographic assessment of the posterior compartment should aim at identifying the number, size, and anatomical location of DE nodules affecting these structures[18]; however, IDEA does not explicitly articulate specifics of USL imaging and measurements on ultrasound. Therefore, the findings of this systematic review regarding ultrasound imaging methods of USLs including the normal and pathological ultrasound characteristics have been summarized below.

Ultrasound Techniques

TVS is an accurate method for identifying endometriosis providing correct techniques are used to adequately assess structures.[45] Using correct techniques in visualizing USLs will assist in improving detection rates of endometriotic lesions.[3] There was variability in the descriptors used to outline the ultrasound technique used, none of which have been validated and their reproducibility has not been evaluated.

Currently, there are 3 industry standard references which outline ultrasound techniques: an educational paper by Leonardi et al,[4] the 2016 IDEA[18] consensus opinion, and the Enzian classification consensus.[47] Although these references were excluded from this review, they are useful as comparative points of reference to industry standard. The descriptions pooled from the included papers were in line with the detailed technique for normal USLs suggested in the paper by Leonardi et al.[4] However,

Figure 3. Transducer position in the posterior fornix. **A**, Posterior fornix transducer position in a longitudinal/midsaggital plane angled inferolaterally to visualize the cervix. Rotate obliquely 45° to evaluate uterosacral ligaments. The dotted black line shows the relationship between the posterior cervical lip and bottom of the posterior cul-de-sac. Lesions above this line are more common and often are associated with uterosacral ligament deep infiltrative endometriosis (DE). **B**, Posterior fornix transducer position in a longitudinal/midsaggital plane of a retroverted uterus is folded back on uterosacral ligaments. With permission from Young et al.[45]



15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

as an educational editorial, this article is based on expert opinion and has a potential risk of bias. Further external validity of the technique suggested by Leonardi et al[4] has not yet been performed.

Only 1 paper[28] of the included articles provided detailed descriptions for additional techniques to implement when abnormal USLs are detected. This is in contrast to the IDEA[18] group recommendation that a hypoechoic lesion within the hyperechoic USL should be measured in 3 orthogonal planes,[5] which was only described by Zhang et al[28] in this review. Similarly, the same study by Zhang et al[28] describes "all of involved targets, especially painful sites, were evaluated in multiple scanning planes by rotating the transducer." Based on improvements in endometriosis diagnosis using techniques outlined in the IDEA consensus, improved diagnosis can be achieved more widely by following the recommended guidelines with attention to patient-guided tenderness.

Table 6 compares the results of this review to the current clinical recommendations and opinions as outlined by the industry standard references.[4,18,47] This comparison highlights several differences between the steps used in the included papers and those recommended by industry standard.

The industry standard references[4,18,47] include steps in their recommended US technique protocols that were not steps identified in any of the papers included in this review. The IDEA[18] consensus specifically recommends identifying the number and size of any USL nodules (Table 6, 11a), which was not reported in the included papers. Also, the description of anatomical location of any USL nodules or extension into surrounding structures[4,18] has not been used in the publications reviewed (Table 6, 11b); however, this was described well in the industry references.[4,18,47] The recommendations proposed by the Enzian[47] classification system directs that DE lesions should be measured in its most lateral extension (Table 6, 11c). This is in contrast with IDEA[18]; however, the Enzian[47] classification is considered by the sum of all visible areas affected by DE, not exclusive to USLs. The Enzian[47] classification allows for both diagnostic and surgical correlation,[47] and is useful in enabling the use of consistent language for classification of endometriosis between TVS and laparoscopic surgery.[47,48] Similar to IDEA,[18] the Enzian[47] classification has been created through a consensus process and like the previously discussed classification systems, needs validation regarding its clinical validity, accuracy, and reproducibility.[47,48]

There are some differences when comparing published studies because throughout the study findings, authors use different terminology for the same structures and locations. While there is still lack of agreement, standardization, and validation of these techniques, and until further evidence-based research emerges, following Leonardi et al[4] is recommended as clinical guidance by visualizing the USLs via the posterior fornix (Figure 3, A and B.) in the midsagittal plane with a slight 45° rotate each side as outlined in Table 6. Currently, it is the only available robust method for USL ultrasound technique despite its lack of validation. Even with the limitation that some experience maybe needed with gynecological ultrasound to assess the posterior compartment reliably,[18] we recommend that when performing a gynecological ultrasound, an effort should be made to examine the posterior compartment and USLs to better understand the anatomy. For further information see Leonardi et al's[4] online supplemental video S1, which demonstrates the midsagittal scan plane and rotation of the transvaginal probe to visualize the right USL (https://onlinelibrary.wiley.com/doi/full/10.1002/ajum.12178).

Bowel preparation was not seen to be a common technique with only 3[24,29,32] of the included studies reported that they used bowel preparation (Table 2). A possible explanation for this might be that previous papers have made reference of bowel preparation having little impact on accuracy[49] and also due to lack of need since the bowel does not lie between the probe and the USL being assessed.[24]

Measurement Techniques

Similar to the ultrasound technique findings, there were inconsistencies in the measurement techniques outlined by the included articles. Zhang et al[28] was the only study to describe measuring at the transverse plane, which is in line with the IDEA[18] consensus.

There were 3 papers[1,27,32] that referenced measurement values of USL and Bazot et al[1] was the only paper that described where the measurements were taken (proximal) and that the "thickness of nodular endometriotic USLs was 8.6 (range, 5–14) mm." Although Robinson et al[27] did not report on measurement sites, there was detailed descriptions of USL

15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

measurements with and without endometriosis. It was concluded by Robinson et al[27] that "there was no significant difference between the measurements in patients with and without endometriosis of the USL area." On the other hand, Chowdary et al[32] state that USLs are "thickened if they were assessed to be greater than 3 mm." There was no validation of either of these results.

Currently, there is no conclusive descriptive measurement for the ultrasound diagnosis of USL DE. Our results show that uncertainty and variation remain on reproducing an accurate measurement and understanding what the values represent. The 2016 IDEA[18] guidelines recommend measuring transversely at the insertion of the ligament on the cervix, however, as normal thickness of USL is not currently known, this is not able to be implemented. In addition, the standard anatomic plane for reproducible measurements has not been established, which therefore requires a further modification of the IDEA technique. Having a reproducible standard will help to improve diagnostic accuracy.

Ultrasound Characteristics of USLs

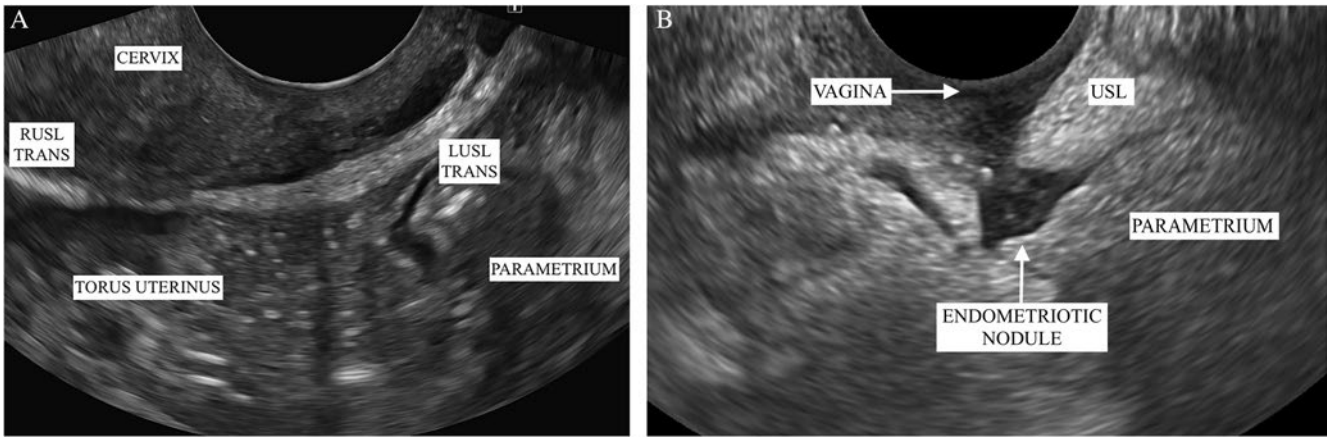
Advances in ultrasound detection of endometriosis call for clear and reproducible ultrasound criteria of the posterior compartment and USLs.[3,4,18] Understanding the normal and abnormal characteristics of USLs will increase TVS performance and improve reporting standardization in diagnosing endometriosis[3] (Figure 4).

Findings from the pooled data of ultrasound characteristics of USLs rarely described the criteria used for normal USL findings. Even so, within all papers combined agreement is that normal USLs appeared as a smooth linear,[36] hyperechoic,[27,35] and homogeneous[1] structure that slides freely over the vaginal wall when transducer pressure is applied and released.[27] (Figure 5A.)

Abnormal characteristics of USLs were reported consistently in 20 studies.[1,14,16,24 31,33,35 42] While generally the criteria were in agreement, the descriptors used were inconsistent and varied with no interobserver agreement. There was some terminology inconsistency for example the USL was described as "white line" in Robinson et al[27] The term "stiffening" was used to describe DE appearances in Yin et al[35] and Zhang et al.[28] Although this most probably refers to immobility (Figure 5, E and F), the true meaning is unclear.

The combined agreement is that USLs were considered to have endometriotic involvement when they appeared thickened with some heterogenous changes (Figure 5B) and/or when there is hypoechoic linear thickening with regular or irregular margins of the USL. Endometriotic nodules were visualized as a solid hyperechoic nodule with regular, irregular, or stellate margins that were tender on sonopalpation and fixed to the surrounding pelvic structures (Figure 5, C–E).

Figure 4. Sonographic appearance of uterosacral ligaments (USLs). **A**, transvaginal ultrasound (TVS) image demonstrating normal anatomy of the USL in the transverse plane. **B**, TVS image demonstrating an endometriotic nodule of the USL in the midsagittal plane.



15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

El-Maadawy et al[40] described 2 new sonographic signs that were associated with bilateral USL involvement showing TU plaques called the "butterfly" and "tram-track" signs. The butterfly configuration is seen in the transverse plane with bilateral USL DE showing torus plaques. The tram-track configuration is seen in the sagittal plane caused by thickened USL and rectal bowel loop involvement increased tissue echogenicity caused by associated perilesional fibrotic and chronic inflammatory changes. No other papers described these observations, and the reproducibility needs validation as currently they are a subjective finding.

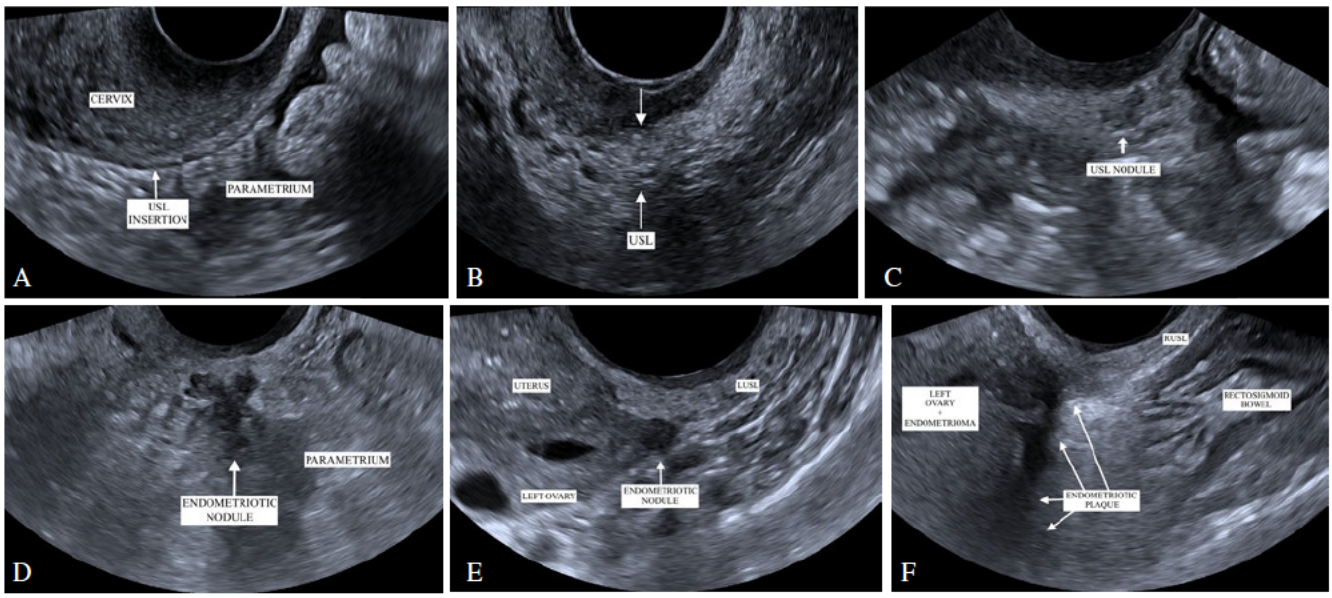
With the variability of USL characteristics seen on TVS, there is a need for classification systems to grade endometriosis lesion extent and location. There was 1 proposed classification system USL DE in the reviewed articles. Zhang et al[14] introduced a system which summarized 4 types according to ultrasound characteristics. In contrast, the classification system proposed by Leonardi[4,50] aims to determine whether a DE nodule is contained within the USL or extends into the parametrium and/or TU. While both systems provide an approach to describe USL disease and has the potential to assist sonographers to quickly and accurately identify USL lesions, neither classification systems have demonstrated reproducibility.

Site-Specific Tenderness

Endometriosis of the USLs is associated with dyspareunia.[51] Tenderness-directed scanning has been described as a useful component of ultrasound technique.[29] Young et al[29] reported that coaching the patient before the scan, explaining that reproduction of pain symptoms was a potential advantage of the diagnostic technique, was adequate to ensure patient compliance.

Although no published papers were found that specifically mentioned pain correlation with changes of USLs in the diagnosis of DE, step 2 of the IDEA[18] guidelines involve checking for "soft markers" such as SST including over the USLs. Identifying SST has been shown to be useful when scanning for DE as tenderness-guided

Figure 5. Transvaginal ultrasound (TVS) ultrasound images of normal uterosacral ligament (USL) and various forms of endometriotic infiltration. **A**, Normal USL seen as a thin, hyperechoic, homogeneous, smooth structure with adjacent physiological fluid. **B**, Grossly thickened USL with some heterogenous changes with associated pouch of Douglas (POD) obliteration and adherent ovary with endometrioma. **C**, A hypoechoic endometriotic nodule (arrow) confined to the USL. The USL itself is also seen to be thickened and more heterogeneous. **D**, Endometriotic nodule of the USL with extension infiltrating into the parametrium. **E**, Irregular, solid endometriotic nodule (arrow) extending to posteriorly with adherence of the left ovary to the uterus and the left uterosacral ligament (LUSL). **F**, Obliterated POD with extensive deep infiltrative endometriosis (DE) demonstrated by focal endometriosis plaque at the level of the rectosigmoid bowel with tethering to the inferior margin of the ovaries, cervix with extension to the right USL. The left ovary is seen here adhered medially and posteriorly at the pouch of Douglas with a large endometrioma present causing immobility of the right uterosacral ligament (RUSL).



15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

sonography is a key approach in pathological site detection therefore should be documented. Furthermore, DE nodules have different characteristics depending on the anatomical location and assist identification with tenderness on probe pressure[40] and when attention is given to site tenderness during examination a high specificity of 94% is achieved in the detection of DE.[52]

The included papers provided little guidance on the details to be collected regarding SST during TVS. No paper mentioned the use of a pain scale such as a visual analog or numerical rating scale to capture the severity of pain during TVS. Without this information it is difficult to determine the correlation of SST to endometriotic nodules, and therefore difficult to determine the true utility of SST in TVS of the USLs. Furthermore, previous research has shown TVS can be painful for women presenting with gynecological problems other than endometriosis.[53] Therefore, pain with TVS may have adequate sensitivity in endometriosis of the USLs but not be a specific finding.[53] Future research should correlate pain severity of SST during TVS to the presence of endometriotic nodules, as well as investigate the sensitivity of pain with TVS in endometriosis.

Limitations and Risk of Bias

A limitation of the included articles was that many papers had insufficient data. Some scan methodologies show promise but had low participation numbers.[26,35,36,39,40] No papers included a power analysis,[35] and there was inconsistent reporting of data, which places uncertainty on the quality of the results. It was unclear if some papers used a reference standard[29,36] for all participants. Furthermore, some authors have used only laparoscopic surgery,[26,34] some have used surgery plus histopathology[33] for diagnosis. In 1 case, surgery was performed before the ultrasound[37] increasing diagnostic bias.

Generally, a reference standard was used, but often the surgeon was not blinded[14,24,26,30,40,41] to the ultrasound findings which could have influenced the surgeon to diagnose DE if it was already reported as seen on TVS at tertiary centers. However, imaging is essential for diagnostic purposes and ultrasound findings are essential in assistance with surgical approach when there is obliteration of the POD to accurately diagnose DE of the bowel or USL. Ethically and legally, imaging findings need to be communicated to the surgeon for surgical planning and mapping, making it challenging to design unbiased methods.

When performing diagnostic tests for endometriosis, the outcome relies on level of skill and experience of the operator undertaking the reference test. Most papers do not report clearly the experience of teams involved or the number of surgeons used, and while many of the techniques used have reported high outcomes, only descriptive reporting was used with no interobservational or intraobservational validation.[28,32,34,37,38,40] Ultrasound characteristics of USLs have been described via a range of techniques including TVS,[1,14,16,24 42] 3D ultrasound,[31,38,39] sonovaginography (SVG),[26,41] TVS magnetic resonance imaging (MRI) fusion,[34] transrectal ultrasound (TRUS),[40] rectal water-contrast TVS (RWC-TVS),[41] and rectal endoscopic sonography (RES)[33] (Table 2), with consensus seen among different approaches.

Importantly, all of studies were in tertiary centers for endometriosis in populations with a high prevalence of DE in the posterior compartment with dedicated gynecologists, sonologists or radiologist performing the ultrasounds. This is a critical gap in relevance to general settings as there needs to be clearer validated criteria available and training of sonographers and radiologists in a general radiology setting for these techniques to be reliable. The limitation of these techniques is that ultrasound training in the assessment of endometriosis has added technical complexity and learning curve, therefore appropriate exposure and training are required.

Lastly, there was only 1 paper[41] that described the ethnicity of patients so it is unknown that the results are reproducible across different ethnic backgrounds.

Future Research Recommendations

Considering the evidence-based results and limitations discussed in this review, there is recommended potential for future research. First, further research for validation of proper techniques and characterizing to better understand the US diagnostic characteristics of USL DE, including standardization in techniques, consistency in terminology, and improved understanding of normal USLs to better understand abnormal USLs.

Finally, more research to determine whether TVS is reproducible in general settings, and whether

15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

additional training is needed for sonographers and radiologists in a general radiology setting.

Conclusion

Through review of the current literature, this study has investigated ultrasound techniques and characteristics of USLs for the diagnosis of DE. The included papers used various approaches such as TVS,[1,14,16,24 42] 3D ultrasound,[31,38,39] SVG,[26,41] TVS MRI fusion,[34] TRUS,[40] RWC-TVS,[41] and RES,[33] with current evidence demonstrating that TVS is considered a first-line investigation in patients with pelvic pain.[18] Recent advances in TVS ability to work-up endometriosis[1,11,18,30,35,40,42,46] have been well documented in the available literature, including USLs with DE infiltration.[4,20,24,28,34] With these developments and the fact that TVS is non-invasive, accessible, well-tolerated, and cost-effective technique,[8] it is essential to have clear and reproducible ultrasound criteria for diagnosis to enable ultrasound diagnosis of DE[8] to improve reporting standardization in the diagnosis of endometriosis.

All papers included in this review reported presence of pathological sonographic findings of the USLs when DE was present[1,14,16,24 42]; therefore, it is recommended that USL examination become a part of TVS exams when DE is clinically suspected. This study also demonstrated that there was lack of data and no agreement when it comes to measuring USLs with DE. Published literature has outlined sonographic descriptors of USL thickening and nodules, but there are no data available in relation to the best sites for measurement of USL, as some papers suggest measuring at the thickest point[34] whereas others measure at the proximal insertion on the cervix.[1,28,31,33] Furthermore, the different methods described have inconsistent descriptors and varying terminology with no interobservational or intraobservational validation. Although there is uncertainty and variation of reproducing an accurate measurement with no validation of what the measurement values represent, the current evidence demonstrates that scanning the USLs, and locating, identifying, and describing USL thickening and endometriotic nodules in the various locations using the described techniques and characteristics in this review has clinical value in early diagnosis. Despite these heterogeneous findings, they are still in line with the IDEA[18] consensus and Leonardi et al[4] with no evidence of direct contradiction. It is therefore the recommendation of this review to continue to follow the IDEA[18] consensus and Leonardi et al[4] for clinical guidance until further evidence-based findings become available.

In saying this, while the data support acceptable accuracy of the criteria used, the performance of TVS in diagnosing DE is highly dependent on the examiner's experience.[46] The current reviewed studies have been performed in a specialist center by experienced sonologists or radiologists and therefore application in a general clinical setting should be considered with caution. Further studies are needed to revise, refine, and validate the techniques used, as well as ensure focus on sonographer and radiologist education so that they can be applied to general settings to examine the reliability of IDEA[18] consensus on implementation. Establishing these techniques and validating protocols would result in earlier, more consistent, and accurate diagnoses.

Acknowledgment

Open access publishing facilitated by University of South Australia, as part of the Wiley - University of South Australia agreement via the Council of Australian University Librarians.

References

1. Bazot M, Thomassin I, Hourani R, Cortez A, Darai E. Diagnostic accuracy of transvaginal sonography for deep pelvic endometriosis. *Ultrasound Obstet Gynecol* 2004; 24:180–185.
2. Zondervan KT, Becker CM, Koga K, Missmer SA, Taylor RN, Viganò P. Endometriosis. *Nat Rev Dis Primers* 2018; 4:9.
3. Scioscia M, Scardapane A, Virgilio BA, Libera M, Lorusso F, Noventa M. Ultrasound of the uterosacral ligament, parametrium, and paracervix: disagreement in terminology between imaging anatomy and modern gynecologic surgery. *J Clin Med* 2021; 10:1–11.
4. Leonardi M, Condous G. A pictorial guide to the ultrasound identification and assessment of uterosacral ligaments in women with potential endometriosis. *Australas J Ultrasound Med* 2019; 22: 157–164.

15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

5. O'Hara R, Rowe H, Fisher J. Managing endometriosis: a cross-sectional survey of women in Australia. *J Psychosom Obstet Gynaecol*. 2022; 43:265–272.
6. Indrielle-Kelly T, Fruhauf F, Fanta M, et al. Diagnostic accuracy of ultrasound and MRI in the mapping of deep pelvic endometriosis using the International Deep Endometriosis Analysis (IDEA) consensus. *Biomed Res Int* 2020; 2020:3583989.
7. Zhou Y, Su Y, Liu H, Wu H, Xu J, Dong F. Accuracy of transvaginal ultrasound for diagnosis of deep infiltrating endometriosis in the uterosacral ligaments: systematic review and meta-analysis. *J Gynecol Obstet Hum Reprod* 2021; 50:101953.
8. The Members of the Endometriosis Guideline Core Group, Becker CM, Bokor A, et al. ESHRE guideline: endometriosis. *Human Reprod Open* 2022; 2022:hoac009. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8951218/pdf/hoac009.pdf
9. RANZCOG. *Australian Clinical Practice Guideline for the Diagnosis and Management of Endometriosis*. Melbourne, Australia: Royal Australian and New Zealand College of Obstetrics and Gynaecology: 2021.
10. Practice bulletin no. 114: management of endometriosis. *Obstet Gynecol* 2010; 116:223–236.
11. Pascoal E, Wessels JM, Aas-Eng MK, et al. Strengths and limitations of diagnostic tools for endometriosis and relevance in diagnostic test accuracy research. *Ultrasound Obstet Gynecol* 2022; 60: 309–327.
12. Condous G. The importance of pre-operative ultrasound diagnosis of pouch of Douglas obliteration. *Australas J Ultrasound Med* 2013; 16:1–2.
13. Reid S, Lu C, Casikar I, et al. The prediction of pouch of Douglas obliteration using offline analysis of the transvaginal ultrasound "sliding sign" technique: inter- and intra-observer reproducibility. *Hum Reprod* 2013; 28:1237–1246.
14. Hudelist G, Ballard K, English J, et al. Transvaginal sonography vs. clinical examination in the preoperative diagnosis of deep infiltrating endometriosis. *Ultrasound Obstet Gynecol* 2011; 37: 480–487.
15. Deslandes A, Parange N, Childs JT, Osborne B, Bezak E. Current status of transvaginal ultrasound accuracy in the diagnosis of deep infiltrating endometriosis before surgery: a systematic review of the literature. *J Ultrasound Med* 2020; 39:1477–1490.
16. Bazot M, Lafont C, Rouzier R, Roseau G, Thomassin-Naggara I, Darai E. Diagnostic accuracy of physical examination, transvaginal sonography, rectal endoscopic sonography, and magnetic resonance imaging to diagnose deep infiltrating endometriosis. *Fertil Steril* 2009; 92:1825–1833.
17. Chapron C, Fauconnier A, Vieira M, et al. Anatomical distribution of deeply infiltrating endometriosis: surgical implications and proposition for a classification. *Hum Reprod* 2003; 18:157–161.
18. Guerriero S, Condous G, van den Bosch T, et al. Systematic approach to sonographic evaluation of the pelvis in women with suspected endometriosis, including terms, definitions and measurements: a consensus opinion from the International Deep Endometriosis Analysis (IDEA) group. *Ultrasound Obstet Gynecol* 2016; 48:318–332.
19. Fratelli N, Scioscia M, Bassi E, Musola M, Minelli L, Trivella G. Transvaginal sonography for preoperative assessment of deep endometriosis. *J Clin Ultrasound* 2013; 41:69–75.
20. Gerges BLW, Leonardi M, Mol BW, Condous G. Meta-analysis and systematic review to determine the optimal imaging modality for the detection of uterosacral ligaments/torus uterinus, rectovaginal septum and vaginal deep endometriosis. *Hum Reprod Open* 2021; 4:hoab041. https://doi.org/10.1093/hropen/hoab041.
21. Moher. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Sys Rev* 2015; 4:1.
22. Covidence. *Covidence Systematic Review Software*. Melbourne, Australia: Veritas Health Innovation; 2021. https://www.covidence.org/
23. CASP (Critical Appraisal Skills Programme). CASP diagnostic test study checklist; 2018. https://casp-uk.b-cdn.net/wp-content/uploads/2018/03/CASP-Diagnostic-Checklist-2018_fillable_form.pdf. Accessed June 5, 2021.
24. Ros C, de Guirior C, Mension E, et al. Transvaginal ultrasound for the diagnosis of endometriosis in the uterosacral ligaments, torus uterinus and posterior vaginal fornix: a prospective study. *Ultrasound Obstet Gynecol* 2021; 58:926-932.
25. Vimercati A, Achilarre MT, Scardapane A, et al. Accuracy of transvaginal sonography and contrast-enhanced magnetic resonance-colonography for the presurgical staging of deep infiltrating endometriosis. *Ultrasound Obstet Gynecol* 2012; 40:592–603.
26. Bratila E, Comandasu DE, Coroleuca C, et al. Diagnosis of endometriotic lesions by sonovaginography with ultrasound gel. *Medicine* 2016; 18:469–474.
27. Robinson AJ, Rombauts L, Ades A, Leong K, Paul E, Piessens S. Poor sensitivity of transvaginal ultrasound markers in diagnosis of superficial endometriosis of the uterosacral ligaments. *J Endometriosis Pelvic Pain Disorders* 2018; 10:10–17.
28. Zhang Y, Xiao X, Xu F, Lin Q, Xu J, Du B. Evaluation of uterosacral ligament involvement in deep endometriosis by transvaginal ultrasonography. *Front Pharmacol* 2019; 10:374.
29. Young SW, Dahiya N, Patel MD, et al. Initial accuracy of and learning curve for transvaginal ultrasound with bowel preparation for deep endometriosis in a US tertiary care center. *J Minim Invasive Gynecol* 2017; 24:1170–1176.
30. Hudelist G, Oberwinkler KH, Singer CF, et al. Combination of transvaginal sonography and clinical examination for preoperative diagnosis of pelvic endometriosis. *Hum Reprod* 2009; 24:1018–1024.
31. Guerriero S, Saba L, Ajossa S, et al. Three-dimensional ultrasonography in the diagnosis of deep endometriosis. *Hum Reprod* 2014; 29:1189–1198.
32. Chowdary P, Stone K, Ma T, et al. Multicentre retrospective study to assess diagnostic accuracy of ultrasound for superficial

15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

endometriosis—are we any closer? *Aust N Z J Obstet Gynaecol* 2019; 59:279–284.

33. Bazot M, Malzy P, Cortez A, Roseau G, Amouyal P, Darai E. Accuracy of transvaginal sonography and rectal endoscopic sonography in the diagnosis of deep infiltrating endometriosis. *Ultrasound Obstet Gynecol* 2007; 30:994–1001.
34. Lima R, Abdalla-Ribeiro H, Nicola AL, Eras A, Lobao A, Ribeiro PA. Endometriosis on the uterosacral ligament: a marker of ureteral involvement. *Fertil Steril* 2017; 107:1348–1354.
35. Yin S, Lin Q, Xu F, Xu J, Zhang Y. Diagnosis of deep infiltrating endometriosis using transvaginal ultrasonography. *Front Med* 2020; 7:567929.
36. Millischer AE, Salomon LJ, Santulli P, Borghese B, Dousset B, Chapron C. Fusion imaging for evaluation of deep infiltrating endometriosis: feasibility and preliminary results. *Ultrasound Obstet Gynecol* 2015; 46:109–117.
37. Holland TK, Cutner A, Saridogan E, Mavrelos D, Pateman K, Jurkovic D. Ultrasound mapping of pelvic endometriosis: does the location and number of lesions affect the diagnostic accuracy? A multicentre diagnostic accuracy study. *BMC Womens Health* 2013; 13:43.
38. Guerriero S, Alcazar JL, Pascual MA, et al. Deep infiltrating endometriosis: comparison between 2-dimensional ultrasonography (US), 3-dimensional US, and magnetic resonance imaging. *J Ultrasound Med* 2018; 37:1511–1521.
39. Grasso RF, Di Giacomo V, Sedati P, et al. Diagnosis of deep infiltrating endometriosis: accuracy of magnetic resonance imaging and transvaginal 3D ultrasonography. *Abdom Imaging* 2010; 35: 716–725.
40. El-Maadawy SM, Alaaeldin N, Nagy CB. Role of preoperative ultrasound mapping in the surgical management of deep infiltrating endometriosis: a prospective observational study. *Egypt J Radiol Nucl Med* 2021; 52:159.
41. Barra F, Leone Roberti Maggiore U, Evangelisti G, et al. A prospective study comparing rectal water contrast-transvaginal ultrasonography with sonovaginography for the diagnosis of deep posterior endometriosis. *Acta Obstet Gynecol Scand* 2021; 100: 1700– 1711.
42. Abrao MS, Gonçalves MO, Dias JA Jr, Podgaec S, Chamie LP, Blasbalg R. Comparison between clinical examination, transvaginal sonography and magnetic resonance imaging for the diagnosis of deep endometriosis. *Hum Reprod* 2007; 22:3092–3097.
43. Miranda-Mendoza I, Kovoor E, Nassif J, Ferreira H, Wattiez A. Laparoscopic surgery for severe ureteric endometriosis. *Eur J Obstet Gynecol Reprod Biol* 2012; 165:275–279.
44. De Graaff AA, Dirksen CD, Simoens S, et al. Quality of life outcomes in women with endometriosis are highly influenced by recruitment strategies. *Hum Reprod* 2015; 30: 1331–1341.
45. Young SW, Groszmann Y, Dahiya N, et al. Sonographer-acquired ultrasound protocol for deep endometriosis. *Abdom Radiol* 2020; 45:1659–1669.
46. Tammaa A, Fritzer N, Lozano P, et al. Interobserver agreement and accuracy of non-invasive diagnosis of endometriosis by transvaginal sonography. *Ultrasound Obstet Gynecol* 2015; 46: 737–740.
47. Keckstein J, Saridogan E, Ulrich UA, et al. The #Enzian classification: a comprehensive non-invasive and surgical description system for endometriosis. *Acta Obstet Gynecol Scand* 2021; 100:1165–1175.
48. Lee SY, Koo YJ, Lee DH. Classification of endometriosis. *Yeungnam Univ J Med* 2021; 38:10–18.
49. Hudelist G, English J, Thomas A, Tinelli A, Singer C, Keckstein J. Diagnostic accuracy of transvaginal sonography (TVS) for non-invasive diagnosis of rectosigmoidal endometriosis—a systematic review and meta-analysis. *Geburtshilfe Frauenheilkd* 2011; 37:257–263.
50. Leonardi M, Martins WP, Espada M, Arianayagam M, Condous G. Proposed technique to visualize and classify uterosacral ligament deep endometriosis with and without infiltration into parametrium or torus uterinus. *Ultrasound Obstet Gynecol* 2020; 55:137–139.
51. Montanari E, Dauser B, Keckstein J, Kirchner E, Nemeth Z, Hudelist G. Association between disease extent and pain symptoms in patients with deep infiltrating endometriosis. *Reprod BioMed Online* 2019; 39:845–851.
52. Guerriero S, Ajossa S, Gerada M, Virgilio B, Angioni S, Melis GB. Diagnostic value of transvaginal "tenderness-guided" ultrasonography for the prediction of location of deep endometriosis. *Hum Reprod* 2008; 23:2452–2457.
53. Van den Bosch T, Verguts J, Daemen A, et al. Pain experienced during transvaginal ultrasound, saline contrast sonohysterography, hysteroscopy and office sampling: a comparative study. *Ultrasound Obstet Gynecol* 2008; 31:346–351.

15509613, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/jum.16129 by Shae Maple - NHMRC National Cochrane Australia , Wiley Online Library on [29/11/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

2.3 Discussion and Conclusion

2.3.1 Key Findings

The concluded systematic review (Maple et al., 2023)[68] of 22 articles revealed that TVS is an accurate method for diagnosing endometriosis when performed using correct techniques, such as those outlined in the IDEA[22] consensus. However, the diagnostic outcomes heavily depend on the examiner's experience, with studies predominantly conducted in specialist settings by highly trained professionals[68].

Visualisation of the USLs, achieved through the posterior fornix in the midsagittal plane with a slight 45° rotation to each side[22,25,47,68], may improve detection rates for endometriotic lesions[47]. Despite its potential, this technique remains unvalidated for assessing USLs with TVS[47], highlighting the need for clear, reproducible ultrasound criteria to standardise reporting and improve diagnostic accuracy in general imaging settings. Incorporating USL assessment into routine TVS protocols could be beneficial for diagnosing DE.

Three definitions were consolidated from the review[68] to describe USL ultrasound characteristics:

Normal USLs: *"Smooth, linear, hyperechoic and homogeneous structure that slides freely over the vaginal wall when transducer pressure is applied and released"*

Abnormal USLs: *"Thickened with some heterogenous changes and/or when there is hypoechoic linear thickening with regular or irregular margins of the USL"*

USL Nodules: *"Solid hypoechoic nodule with regular, irregular or stellate margins that were tender on sonopalpation and fixed to the surrounding pelvic structures"*

The review identified several gaps in the literature:

1. **Examiner Experience**: TVS diagnostic performance for DE heavily depends on the operator's experience. Studies conducted in specialist centres are not directly applicable to general clinical settings. Further research is needed to validate and standardise techniques for use by general sonographers and radiologists.
2. **Measurement of USLs**: While some sonographic descriptors of USL thickening exist, no consensus has been reached on the best sites for measurement.

3. **Pain Correlation**: Although endometriosis of the USLs is linked to dyspareunia, no studies specifically correlated site-specific tenderness with ultrasound findings. Future research should explore the relationship between pain severity and sonographic changes in USLs.

2.3.2 Novel Contribution to Literature

This review provides a detailed evaluation of ultrasound techniques and criteria for diagnosing endometriosis in the USLs, a topic not previously explored in depth. It summarised imaging methods and consolidated normal and pathological characteristics while highlighting a high level of agreement in studies conducted in specialist settings. However, the applicability of these findings to general clinical settings remains uncertain.

The review revealed reporting gaps: only 11 of 22 studies described USL visualisation techniques, and no study provided a comprehensive or validated method. While 20 of 22 studies outlined abnormal USL criteria, only 5 defined normal characteristics. These findings highlight the urgent need for standardised criteria and training to enhance the utility of ultrasound for USL assessment in general practice. Establishing validated protocols could lead to earlier, more consistent, and accurate diagnoses of endometriosis.

2.3.3 Strengths and Limitations

This systematic review adhered to explicit, rigorous, and reproducible methodologies, ensuring its high quality.

However, limitations were identified in the studies reviewed. These included:

1. Small sample sizes, lack of power analyses, and inconsistent data reporting all of which limit the reliability of the findings.
2. Variability in diagnostic approaches, such as reliance on laparoscopic surgery alone or in combination with histopathology, further complicated comparisons.
3. Some studies introduced bias by performing surgery before imaging, and unblinded surgeons may have been influenced by prior ultrasound results.

Most research was conducted in tertiary centres with highly experienced clinicians, limiting its applicability to general practice. The technical complexity of ultrasound for endometriosis, coupled with its steep learning curve, highlights the need for standardised protocols and targeted training for use in general radiology settings. Addressing these

challenges is essential for improving the reliability and generalisability of ultrasound in diagnosing endometriosis.

2.4 Updated Search of the Literature

The search was repeated to identify up to date literature on 16th November 2024. This search revealed 26 articles (2 of which were duplicates). After title and abstract review, 11 articles underwent full text review and 5 were met the inclusion criteria and ultimately included for analysis[47,71-73]. Exclusions included 17 papers that did not meet the inclusion criteria, one paper was our published systematic review[68] and another 2 papers that cited data directly from our review[21,74].

The findings were consistent with the original review[68] but added new insights. As summarised in Table 4, none of the new studies described the appearance of normal USLs on TVS, but four addressed abnormal USLs. Only one detailed the technique for USL visualisation, highlighting the importance of precise methodology[47].

Despite these additions, the review reaffirmed inconsistent descriptors, varying terminology and standardised techniques for USL assessment in general settings (Table 5). No conclusive measurements for USL DE diagnosis were identified, nor were values

TABLE 4. Summary of ultrasound criteria and technique descriptions used studies from the updated search of the literature.

Author	**Specialist Centre**	**Operator**	**TVS Technique**	**Normal USL**	**Abnormal USL**
Kamkarfar et al, 2022 ([71])	Y	Expert Radiologist in endometriosis	X	X	√
Martire et al, 2023 ([72])	Y	Not Specified	X	X	√
Freger et al, 2024 ([47])	Y	Expert Sonologist	√	X	√
Roditis et al, 2023 ([73])	Y	Experienced Radiologists	X	X	√
Chen et al, 2024 ([75])	Y	Expert Radiologist in endometriosis.	√	X	√

Key: (Y) yes; (X) No description, (√) had description.

TABLE 5. Overview of the Ultrasound Characteristics Used for the Diagnosis of USL in the newly reviewed papers.

Author	USL			USL Nodules		
	Thickened	**Echogenicity**	**Margins**	**Hypoechoic**	**Margins**	**Doppler**
Kamkarfar et al, 2022 ([71])	√			√	√ Irregular	
Martire et al, 2023 ([72])	√	√ Hypoechoic	√ Irregular	√	√ Irregular	√ Avascular
Freger et al, 2024 ([47])			√ Regular or Irregular	√		
Roditis et al, 2023 ([73])	√		√ Regular or Irregular	√ Echoic	√ Regular or Stellate Margins	
Chen et al, 2024 ([75])	√ asymmetric	√	√ Regular or Irregular	√	√ Irregular	√ Avascular

Key: (X) No description, (√) had description.

or measurement planes provided. Notably, Martire et al, 2023[72] and Chen et al, 2024[75] reported that DE of the USLs is typically avascular or poorly vascularised, using colour Doppler imaging. However, the 2024 Society of Radiologists in Ultrasound deferred to existing guidelines[76], which state that colour Doppler is unnecessary for diagnosing DE. An overview of ultrasound descriptors is provided in Table 5, with detailed data in Table 6.

Since publication, this review has been cited by Young et al, 2024[21], Fernandez et al, 2024[74], Freger et al, 2024[47], Chen et al, 2024[75] and Spiers et al, 2024[77]. The Society of Radiologists in Ultrasound (2024)[21] cited the review alongside the IDEA consensus, recommending transvaginal ultrasound of the posterior compartment to improve DE detection. This aligns with the thesis's findings that these techniques are quick to perform and could reduce diagnostic delays[21].

TABLE 6. Findings of abnormal USL descriptions used in the new papers.

Author	Criteria used to describe TVS appearance of USLs
Kamkarfar et al, 2022 ([71])	• Ultrasound findings include nodular aggregations or the presence of irregular hypoechoic nodules, thickening of the wall, or retractable masses and hypoechoic points. • Increased thickness of right and left USLs, the presence of nodules in these ligaments.
Martire et al, 2023 ([72])	• Diagnosis of DE of the USL was made when the presence of irregular avascular (or with poor vascularisation) hypoechogenic tissue was identified disrupting the normal USL appearance of the hyperechoic tissue covering laterally or longitudinally the retrocervical area. • Abnormal retroperitoneal hypoechoic linear or nodular thickening with irregular contours and no or few Doppler signals.
Freger et al, 2024 ([47])	• Suspected DE presents as a hypoechoic nodule within the surrounding hyperechoic USL and should be measured in three orthogonal planes. • USL DE nodules can be regular or irregular and can be confluent with other nodules nearby in the posterior vaginal fornix, bowel, TU or parametrium.
Roditis et al, 2023 ([73])	• Uterosacral ligament was considered involved when a) echoic nodular or linear thickening behind isthmus. • It was visible and bore a nodule (regular or with stellate margins) or hypoechogenic linear thickening with regular or irregular margins.
Chen et al, 2024 ([75])	• DE in USLs showed mainly asymmetric thickening and uneven echogenicity of USLs, irregular lesion morphology, well-defined borders, internal hypoechoicity, and no blood flow signal within the lesion on color Doppler ultrasonography. • In the presence of POD fluid, the morphologic structure of the lesion was more clearly defined.

Key: (USL) uterosacral ligament, (TVS) transvaginal ultrasound, (DE) deep endometriosis, (TU) torus uterinus.

Table 4 highlights operator qualifications and experience, showing all studies were conducted in specialist endometriosis centres by radiologists or sonologists with extensive experience in DE imaging. This underscores the need for validated criteria and training in general settings. As Freger et al. (2024) noted, “Although the USL is the most common location of DE, it remains the most difficult to diagnose due to the small size of

nodules and the lack of clinician experience in evaluating these structures using imaging"[47].

2.4.1 Conclusion of Updated Search of the Literature

The updated review re-confirmed the value of TVS for diagnosing USL DE. However, external validation is still needed.

In line with findings from the review, no further studies from general ultrasound clinics with sonographer-led scanning were identified, highlighting the need for further research to validate techniques and train sonographers and radiologists in general settings. The next chapter investigates the diagnostic reliability of TVS characteristics for normal and abnormal USLs across experienced and less experienced examiners in general imaging practices.

Chapter 3

Ultrasound of the Uterosacral Ligaments: A Reliability Study for Diagnosis of Endometriosis in Australian Non-Specialised Medical Imaging and Radiology Settings

The published article (Maple et al., 2025)[69] forms the basis of this chapter.

Maple, S., Bezak, E., Chalmers, K.J., and Parange, N. (2025), ***Ultrasound of the Uterosacral Ligaments: A Reliability Study for Diagnosing Endometriosis in Australian Non-Specialised Medical Imaging and Radiology Settings***. Australas J Ultrasound Med, 28: e12420. https://doi.org/10.1002/ajum.12420

3.1 Introduction and Motivation

The previous chapter established criteria for identifying normal and abnormal USLs and highlighted the role of TVS in improving endometriosis diagnosis. However, the studies reviewed in Chapter 2 were conducted exclusively in specialised endometriosis or gynaecological pain clinics. In these settings, TVS scans were performed by gynaecologists skilled in ultrasound rather than by sonographers. It remains unclear

whether sonographers and radiologists in general imaging practices can achieve the same level of diagnostic reliability.

An important gap in the literature is the lack of evidence on the reliability and reproducibility of TVS results in general imaging settings. In other words, can sonographers and radiologists with varying levels of experience apply the established criteria to reliably diagnose endometriosis of the USLs?

This chapter presents an intra and interobserver reliability study aimed at evaluating the consistency of TVS characteristics for normal and abnormal USLs. It also examines differences in reliability between experienced and less experienced examiners in a general imaging setting and assesses the correlation between USL thickness and DE. For this study, USL image data were collected from 42 patient participants, with all scans performed by one experienced sonographer. Observers were then asked to review these images and video clips to classify USL ultrasound characteristics based on established criteria, including echogenicity, echotexture, contour, thickness, and the presence of nodules, as identified in the literature review[68].

3.2 Published Journal Article

Pages 76-86 contain the research paper by Maple et al., (2025)[69] as published in *The Australiasian Journal of Ultrasound in Medicine (AJUM)* in February 2025.

Check for updates

Ultrasound of the uterosacral ligaments: A reliability study for diagnosing endometriosis in Australian non-specialised medical imaging and radiology settings

Shae Maple, **Eva Bezak**, **K Jane Chalmers** and **Nayana Parange**

Allied Health and Human Performance, University of South Australia, Adelaide, South Australia, Australia

Abstract

Introduction/Background: Uterosacral ligaments (USL) are the most common sites of endometriosis. Transvaginal ultrasound (TVS) demonstrates high diagnostic accuracy for endometriosis of the USLs using standardised technique and characterisations. While high accuracy and reproducibility is established with these techniques by well-trained professionals, the question still remains if these techniques are reproducible in general settings. This study aims to assess the intra and interobserver agreement of TVS characteristics of USLs, between experienced and less experienced examiners in an Australian general ultrasound imaging practice, where sonographers are required to perform ultrasound for endometriosis.

Methods: Forty-two patients, with and without known endometriosis, underwent ultrasound imaging of the USLs. Images were obtained of uterosacral ligaments and collated for interobserver survey. Six professional observers independently reviewed the images, classifying characteristics such as echogenicity, echotexture, contour, thickness, and presence of nodules. Interobserver reliability was assessed using Gwet's agreement coefficients (*AC1*), and the correlation between USL thickness and endometriosis was analyzed using Spearman's correlation.

Results: Interobserver agreement for detecting USL endometriosis was substantial (*AC1* = 0.63), with an overall agreement of (0.65) for the seven USL characteristics. Intraobserver agreement ranged from moderate (0.60) to almost perfect (0.96). Experience did not significantly affect intraobserver reliability. A strong positive correlation was found between USL thickness and endometriosis ($r = 0.7965$, $P < 0.01$).

Conclusion: This study demonstrates high inter and intraobserver agreement among sonographers and radiologists in a general imaging department for identifying USL characteristics and diagnosing USL endometriosis. Both experienced and less experienced operators can reliably assess USLs Consistency was shown in identifying thickened uterosacral ligaments however, there is no consensus on where uterosacral ligament be measured. Even so, a thickened USL can prompt further extension of the pelvic scan to look for other endometriosis markers.

Keywords: deep infiltrative endometriosis, gynaecology, sonographer, sonography, transvaginal ultrasound, uterosacral ligaments.

Introduction

Endometriosis is a common and painful gynaecological condition affecting approximately 10% of female-born individuals,[1] characterised by endometrial-like tissue growing outside the uterine cavity.[2] This tissue can cause a range of symptoms, including menstrual pain, chronic pelvic pain and infertility.[3,4] In Australia, the average delay in diagnosing endometriosis is currently 6.4 years.[5]

Multiple studies have identified the uterosacral ligaments (USL) as one of the most common sites for deep endometriosis (DE).[3,4,6,7] The USLs are extraperitoneal structures made of connective tissue that form the lateral boundaries of the rectouterine and rectovaginal spaces.[3] Anatomically, the USL is divided

Correspondence to email shae.maple@mymail.unisa.edu.au

doi: 10.1002/ajum.12420

© 2025 The Author(s). *Australasian Journal of Ultrasound in Medicine* published by John Wiley & Sons Australia, Ltd on behalf of Australasian Society for Ultrasound in Medicine.
This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

into three sections: distal (cervical), intermediate and proximal (sacral).[8] The distal section, which attaches to the posterior cervix, is the most easily visualised sonographically[4,8,9] (Figure 1).

Historically, laparoscopy with histological examination was considered the gold standard for diagnosing endometriosis.[10 12] However, advances in the ability and accuracy of transvaginal ultrasound (TVS) have made it the recommended first-line diagnostic tool for endometriosis,[2,9,13 21] helping reduce delays in diagnosis and improve surgical planning.[10] As a result, clear and reproducible ultrasound criteria are becoming increasingly important for diagnosing DE.[10] The International Deep Endometriosis Analysis (IDEA)[9] consensus statement outlines the best ultrasound practices for evaluating pelvic endometriosis, with a systematic approach to assessing both the anterior and posterior compartments. While significant research has focused on endometriosis affecting the rectum and rectosigmoid, which has been well-received within clinical practice,[9,22,23] the role of USLs in the ultrasound diagnosis of endometriosis remains studied.[19,24]

A recent systematic review[24] recommended that USL examination be included in TVS examinations when DE is clinically suspected, as scanning the USLs has demonstrated clinical value in early diagnosis. However, the review also highlighted inconsistent descriptors and varying terminology used to describe USL findings and variation in ultrasound techniques.[24] Importantly, there is currently no data on interobserver agreement regarding TVS for USL assessment.[24] Despite this, recent studies[19] have shown high diagnostic accuracy for assessing DE of the USLs using standardised TVS techniques.[4,19,24,25] Nevertheless, while it is known that TVS is a highly accurate and reproducible method for non-invasive diagnosis of DE by well-trained professionals, the question remains whether these techniques are reproducible in general settings.

Considering this, the aim of this study was to assess the intra- and interobserver agreement and reliability of TVS characteristics of normal and abnormal USLs, including echogenicity, thickness and nodules. This was done among both experienced and less experienced examiners in an Australian general ultrasound practice, where sonographers are responsible for performing ultrasounds to diagnose endometriosis.

Methods

Study design

This study was a prospective intra- and interobserver analysis conducted between November 2021 and September 2022. The methodology adhered to the recommended Guidelines for Reporting Reliability and Agreement Studies (GRRAS) statement.[26] Prior to patient recruitment, a sample size calculation was performed using the G*Power software,[27] version 3.1.9.7, which estimated a minimum sample size of 42 patient participants and five professional observers to achieve significant results with a large effect size, 95% power and a 95% confidence interval.

Study setting and patient population

A total of 42 patient participants who met the inclusion criteria (Figure 2) were included in this study. These patients presented to an outpatient general imaging private practice in South Australia between November 2021 and September 2022, following referrals from general practitioners or gynaecologists. The 42 participants were divided into two groups: 30 with a known history of DE and 12 with no history or symptoms of DE. The 30 patients presenting with endometriosis had been medically diagnosed via either laparoscopy

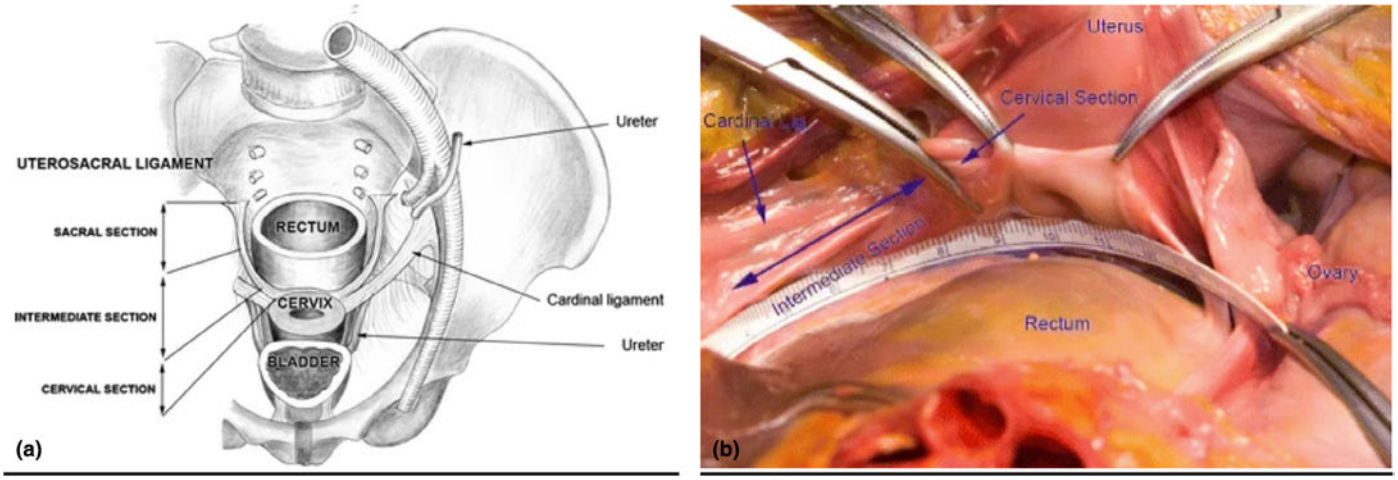


Figure 1: A schematic diagram of the pelvis viewed from above showing the three parts of the uterosacral ligament and its relations with the cardinal ligament near the cervix (a) and, surgical image of the USL demonstrating the three sections and surrounding anatomy (b). The blue arrows are pointing to the corresponding anatomy as labelled. Courtesy: Vu 2010.[8] USL, uterosacral ligaments.

© 2025 The Author(s). *Australasian Journal of Ultrasound in Medicine* published by John Wiley & Sons Australia, Ltd on behalf of Australasian Society for Ultrasound in Medicine.

22050140, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ajum.12420 by National Health And Medical Research Council, Wiley Online Library on [18/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

22050140, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ajum.12420 by National Health And Medical Research Council, Wiley Online Library on [18/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

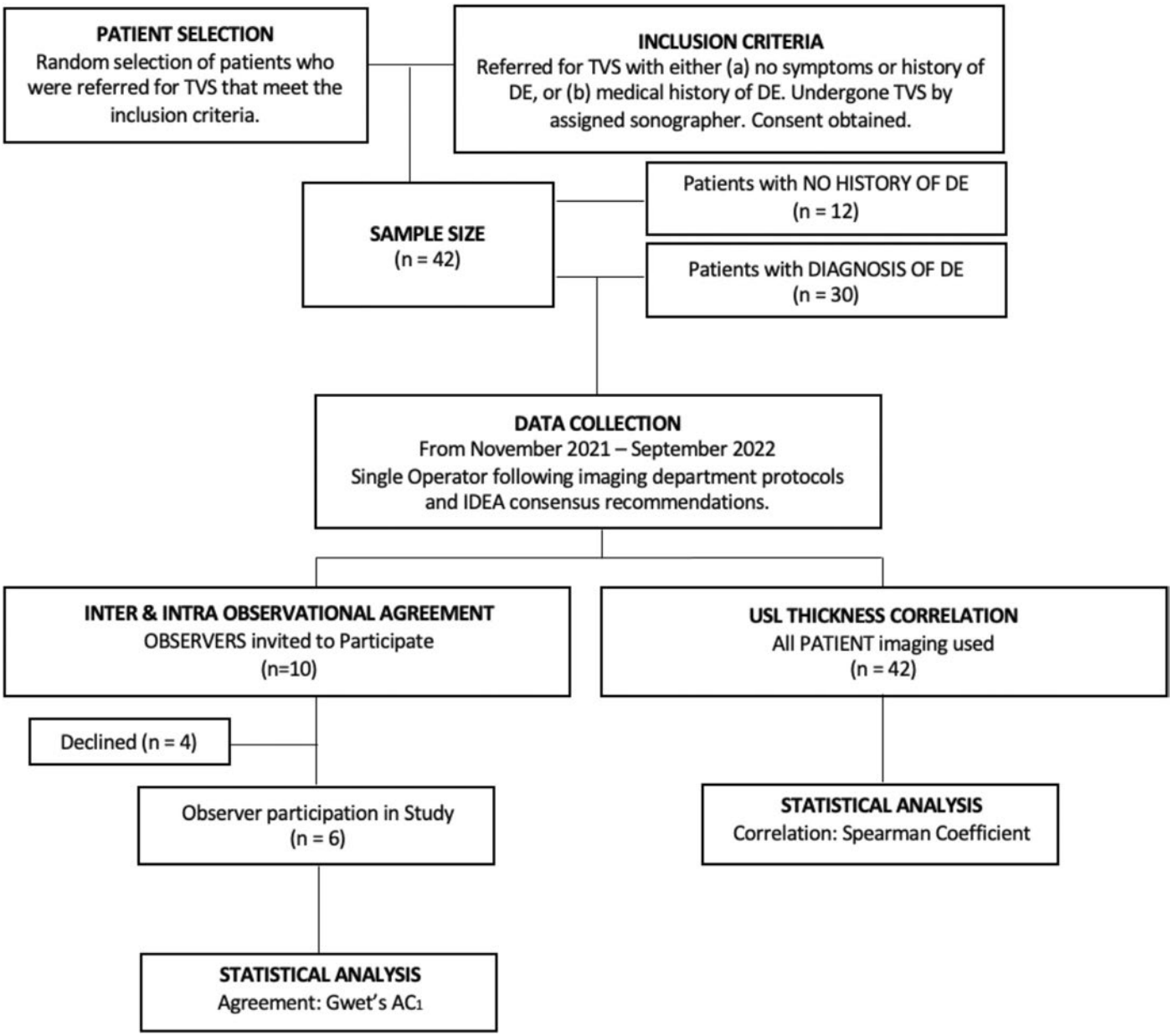


Figure 2: Flow chart summarising the methodology process and the inclusion criteria of eligible patients and observers in the study. AC_1, agreement coefficient; DE, deep endometriosis; IDEA, international deep endometriosis analysis; n, sample size; TVS, transvaginal ultrasound; USL, uterosacral ligaments.

or clinically by a gynaecologist, and all exhibited symptoms suggestive of DE, such as dysmenorrhea, dyspareunia, chronic pelvic pain or infertility.[3,4]

All 42 patient participants had a complete pelvic ultrasound, with TVS that was reported in line with clinic protocols for the referring physician. For each of the 42 patients, images and video clips evaluating the USLs were collated. The images and videos included in this study were selected based on representative diagnostic quality, obtaining a range of images from patients that displayed both normal and abnormal USLs to assess interobserver reliability.

Study objectives

The objective was to find the inter- and intraobserver agreement in identifying ultrasound characteristics of DE in the USLs and ultrasound diagnosis of DE in the USLs across the six observers. This study also aimed to determine the correlation and agreement between USL DE and USL thickness on TVS.

© 2025 The Author(s). *Australasian Journal of Ultrasound in Medicine* published by John Wiley & Sons Australia, Ltd on behalf of Australasian Society for Ultrasound in Medicine.

Data collection and image acquisition

Transvaginal ultrasound was performed by a highly skilled sonographer (SM) with 15 years of professional experience, using Canon i800, Aplio 500, Aplio a550 and Aplio XG (Canon Medical System Corporation, Otawara, Tochigi, Japan) ultrasound machines, equipped with 11CV3, 11CV or 9C3 (3–11 MHz) transvaginal transducers. Each examination included a complete pelvic ultrasound, covering the uterus, cervix, adnexa and ovaries, in accordance with general practice imaging protocols and the Australiasian Society of Ultrasound in Medicine (ASUM) guidelines[28] for gynaecological ultrasound exams as per the referral request. The examination was then extended to assess for endometriosis, following the four-step method outlined in the IDEA consensus,[9,29] which includes evaluation of the uterus, both adnexa, urinary bladder, vagina and rectovaginal septum, USLs and rectosigmoid. To ensure consistency and reproducibility, the recommended ultrasound techniques for visualising the USLs[4,24] were used. This involved placing the transducer in the posterior vaginal fornix, then withdrawing it into the vagina. The transducer was kept in the longitudinal plane and angled inferolaterally to visualise the cervix, before rotating it approximately 45° until the hyperechoic line of the USL was visible.[4,24] Measurements of the USLs were taken and recorded. Endometriosis was diagnosed based on the systematic approach described by the IDEA[9] guidelines.

Interobserver and intraobserver analysis

As noted previously, the sample size calculation indicated that five professional observers were needed to detect a large effect size. After invitations were extended, six observers agreed to participate, as shown in Figure 1. These included five accredited medical sonographers, as per the Australian Sonographers Accreditation Registry (ASAR), and one radiologist accredited by the Royal Australian and New Zealand College of Obstetricians and Gynaecologists (RANZCOG). This multidisciplinary approach, incorporating observers with varying levels of experience and qualifications, was designed to minimise professional bias and better reflect real-world clinical practice.

Each observer reviewed the 42 cases in two separate sessions, approximately 8 weeks apart, to minimise recall bias. In each session, the same 42 cases were assessed, with each case including still images and video clips of the USLs for evaluation. The images were captured in the longitudinal plane, and the video clips provided a sweep through the posterior compartment, including sonopalpation to assess any potential adherence of the USL. Data and images for analysis were compiled for offline review using the Qualtrics software, version XM, June 2023, (Qualtrics, 2023, Provo, UT, USA). Observers were blinded to both the ultrasound outcomes and the responses of other observers, as well as to their own previous assessments.

Each of the six observers was asked to classify the ultrasound characteristics of each USL based on the current literature[24] regarding how USLs should be described. This included evaluating echogenicity, echotexture, margin contour, thickness and the presence of any nodules. Observers were also asked to annotate in a text box where they would measure the USL, with responses categorised into five options: (i) Cervix/insertion, (ii) Thickest point, (iii) At nodule, (iv) Mid-section or (v) Measurement not relevant. Although observers were not required to manually measure each USL, rather to answer subjectively, measurements were taken during the initial TVS examination of all patients, specifically at the thickest point and/or at any identified nodules and recorded for later analysis.

The assessment criteria for the USLs were based on current review[24] findings, which concluded that normal USLs appear as smooth, linear, hyperechoic and homogeneous structures that slide freely over the vaginal wall when transducer pressure is applied and released[24] (Figure 3a). Uterosacral ligaments were considered to have endometriotic involvement if they appeared thickened with heterogeneous changes, or if there was hypoechoic linear thickening with regular or irregular margins (Figure 3b). Endometriotic nodules were identified as solid, hypoechoic nodules with regular, irregular or stellate margins, which were tender on sonopalpation and fixed to the surrounding pelvic structures[24] (Figure 3c).

All USLs were measured longitudinally at the thickest section or at the level of any nodule. Observers were asked to subjectively assess whether the USL appeared thin or thickened, without being shown the recorded thickness values. Since there is no definitive standard measurement for the ultrasound diagnosis of USL DE,[24] previous studies were used as a guide.[30] Uterosacral ligaments were considered thickened if they measured greater than 3 mm,[31] with a thickness greater than 5 mm^2 indicating more significant disease involvement.

Statistical analyses

The inter- and intraobserver reproducibility of TVS for diagnosing endometriosis in the USLs was assessed by calculating reliability and agreement using Gwet's agreement coefficients (AC_1). Corresponding 95% confidence intervals (CIs) were computed to quantify interrater reliability, reflecting the consistency of observers in identifying the diagnostic characteristics of USLs indicative of endometriosis. Interobserver agreement, as interpreted through Gwet's AC_1, was categorised as slight (0.0–0.20), fair (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80) or almost perfect (0.81–1.00)[32] (Figure 4). Statistical analyses were conducted using/SE 18.0 for Mac (Intel 64-bit, revision 04 October 2023.[32]).

To assess the relationship between USL thickness and endometriosis, Spearman's correlation was performed using data from the 42 enrolled patients. The results were interpreted based on the strength of the correlation, with values categorised as strong ($r = 0.7–1$), moderate ($r = 0.5–0.7$) or low ($r = 0.3–0.5$), considering significant correlation values ($P < 0.01$ or $P < 0.05$) (Figure 4). A biostatistician was consulted to ensure the appropriateness of the analysis method.

© 2025 The Author(s). *Australasian Journal of Ultrasound in Medicine* published by John Wiley & Sons Australia, Ltd on behalf of Australasian Society for Ultrasound in Medicine.

22050140, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ajum.12420 by National Health And Medical Research Council, Wiley Online Library on [18/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

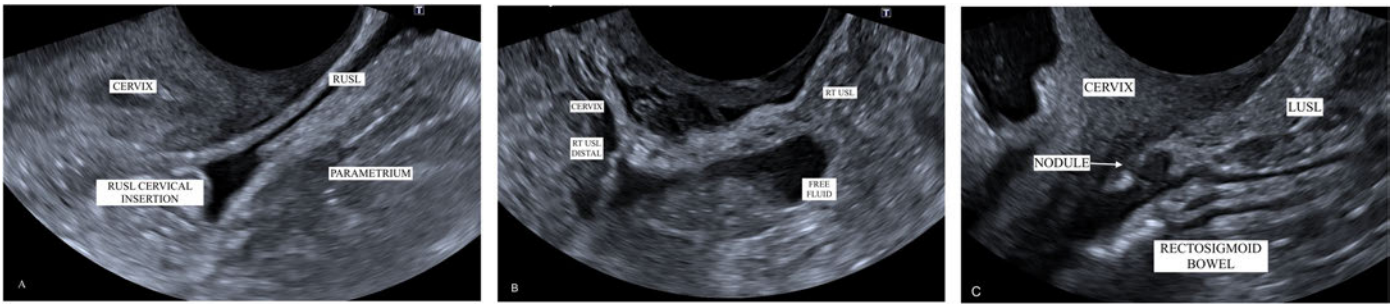


Figure 3: TVS ultrasound images of the USL. (a) a normal USL with a thin, hyperechoic, homogeneous, smooth structure with adjacent physiological fluid in a longitudinal plane. (b) USL with endometriotic involvement in a patient where the USL is highlighted with free fluid and seen to be thickened and heterogeneous with an irregular contour in a patient with endometriotic bowel lesions and background adenomyosis. (c) A hypoechoic endometriotic nodule within the USL at the cervical insertion. TVS, transvaginal ultrasound; USL, uterosacral ligaments.

Gwet AC_1	Interpretation	Spearman (r)	Interpretation
<0	No Agreement		
0.0-0.20	Slight		
0.21–0.40	Fair	0.3 – 0.5	Low
0.41–0.60	Moderate	0.5 – 0.7	Moderate
0.61–0.80	Substantial	0.7 - 1	Strong
0.81-1.00	Almost Perfect		

Figure 4: Scale used in statistics to quantify the level of agreement based Gwet AC_1 values[32] and Spearman coefficient (r) AC_1 values.[32] AC_1, agreement coefficient.

Ethics approval

The study was approved by the University of South Australia Human Research Ethics Committee (project number 204278), and written informed consent was obtained from all participants prior to inclusion in the study.

Results

Patient characteristics and ultrasound data sets

The characteristics of the patient participants and their presenting symptoms are summarised in Table 1. Forty-two (42) female-born patients were included, with a mean age of 33.6 years (range 18–54). Four patients over 50 years old, all with chronic endometriosis, were included in the final analysis. Ultrasound findings suggestive of endometriosis are outlined in Table 2.

Detailed findings related to the USLs on TVS are summarised in Table 3. In patients with known DE, TVS revealed altered echotexture in all 30 USLs (100%), showing a more heterogeneous appearance compared with the homogeneous echotexture observed in participants without endometriosis. Specific ultrasound findings included 12 USL nodules (40%), 27 with irregular margins (90%), and all 30 USLs appearing thickened (100%).

No DE was detected in participants without a history or symptoms of DE. The USLs in these participants were normal and were recognised as such by the observers. However, it is important to address the absence of USL DE characteristics in asymptomatic or undiagnosed patients, particularly given that endometriosis can often be asymptomatic. This may suggest that the lack of detectable changes in the USLs of these patients does not necessarily rule out the presence of endometriosis, as the condition may remain undiagnosed or asymptomatic in many cases.[33] To ensure accurate categorisation, the 12 participants without endometriosis were selected based on their lack of symptoms or indications of DE. These individuals underwent TVS for reasons unrelated to endometriosis, such as polycystic ovarian syndrome, follow-up for endometrial polyps or hyperplasia, or intrauterine contraceptive device location (Table 1). In these cases, they were classified as normal.

Uterosacral ligament measurements varied across participants. In the 12 patients with no history of endometriosis, all

© 2025 The Author(s). *Australasian Journal of Ultrasound in Medicine* published by John Wiley & Sons Australia, Ltd on behalf of Australasian Society for Ultrasound in Medicine.

22050140, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ajum.12420 by National Health And Medical Research Council, Wiley Online Library on [18/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Table 1: Patient characteristics, endometriosis history and indication for performing TVS of the study cohort (n = 42).

	(n = 42)	%
Patient characteristics		
Age	36 (Range 18–54) 33 (Median) 33.6 (Mean)	
No history DE	12	(28.6%)
DE diagnosed laparoscopy	10	(23.8%)
DE diagnosed clinically	7	(16.7%)
DE clinically investigated	13	(31%)
Indication for TVS		
Chronic pelvic pain	26	(61.9%)
Dysmenorrhea	16	(38.1%)
Infertility	6	(14.3%)
Dyspareunia	5	(11.9%)
Other	12	(29%)

DE, deep endometriosis; n, sample size; TVS, transvaginal ultrasound.
'Other' indications for TVS include: bloating, polycystic ovarian syndrome, follow-up for endometrial polyp or hyperplasia, history of ovarian tumour, intrauterine contraception device location and unexplained weight loss.

had USLs measuring <3 mm. Among the 30 patients with known endometriosis, nine (30%) had USLs measuring 3-5 mm, and 21 (70%) had USLs >5 mm, with the thickest measuring 9.2 mm.

Interobserver agreement

According to Gwet AC_1, the results show substantial overall agreement (0.65) for the seven ultrasound characteristics of the USLs across the six observers, confirming consistency and reproducibility. Table 4 demonstrates almost perfect agreement for echogenicity (0.96), substantial agreement for echotexture (0.63), presence of nodules (0.61) and nodule contour (0.63), as well as overall substantial agreement for normal versus abnormal USLs (0.63). Moderate agreement was observed for USL contour (0.42) and thickness (0.47), with fair agreement on the measurement site (0.29).

Table 5 shows substantial agreement (0.63) for the ultrasound diagnosis of endometriosis in the USLs across all six observers. Notably, there was a substantial agreement for patients without a clinical diagnosis of DE (0.66) compared with moderate agreement (0.56) for those with known DE.

Intraobserver agreement

As shown in Table 6, all six observers demonstrated high intraobserver agreement, with values ranging from moderate

Table 2: The findings of endometriosis on ultrasound for the patients with known or suspected history of endometriosis.

Findings of endometriosis on TVS		
	(n = 30)	%
Participants with endometriosis Hx	30	100
Endometriosis present	30	100
Endometrioma	14	46.7
Obliterated POD	4	13.3
Adherent ovaries	21	70.0
Medialised ovaries	9	30.0
Retroverted or rotated uterus	11	36.7
Adenomyosis	19	63.3
Total focal endometriotic lesions	21	70.0
Types of endometriotic lesions:		
Rectosigmoid DE	7	23.3
Rectocervical DE	9	30.0
USL DE (nodule)	12	40.0
Vaginal DE	0	0.0
Bladder DE	0	0.0
Uterine serosal plaques	2	6.7
LSCS scar endometriosis	1	3.3

DE, deep endometriosis; Hx, history; LSCS, lower section caesarean section; n, sample size; POD, pouch of douglas; TVS, transvaginal ultrasound; USL, uterosacral ligamen.

Table 3: Ultrasound characteristics of the USLs on participants with and without history of endometriosis.

USL findings		
	No DE (n = 12)	DE (n = 30)
USL nodule	0	12 (40%)
Heterogeneous/Hypoechoic	0	30 (100%)
Irregular margins	0	27 (90%)
Thickened	0	30 (100%)
Thickness		
<3 mm	12 (100%)	0
3–5 mm	0	9 (30%)
>5 mm	0	21 (70%)

DE, deep endometriosis; mm, millimetres; n, sample size; USL, uterosacral ligaments.

© 2025 The Author(s). *Australasian Journal of Ultrasound in Medicine* published by John Wiley & Sons Australia, Ltd on behalf of Australasian Society for Ultrasound in Medicine.

22050140, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ajum.12420 by National Health And Medical Research Council, Wiley Online Library on [18/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Table 4: Interobserver agreement and Gwet AC_1 Statistics for ultrasound characteristics of USL across 6 observers.

Ultrasound USL characteristic (n = 42)	% Agreement	Gwet AC_1 (95% CI)
Echogenicity	96	0.96 (0.92–0.99)
Echotexture	72	0.63 (0.51–0.75)
Contour of USL	71	0.42 (0.25–0.59)
Nodule present	76	0.61 (0.44–0.78)
Contour of nodule	69	0.63 (0.50–0.76)
Thickness	73	0.47 (0.31–0.63)
No Hx DE (n = 12)	88	0.86 (0.66–1.0)
Hx DE (n = 30)	68	0.42 (0.21–0.63)
Measurement site	39	0.29 (0.24–0.33)
Normal v Abnormal	72	0.63 (0.53–0.74)
Overall	71	0.65 (0.62–0.69)

AC_1, agreement coefficient; CI, confidence interval; DE, deep endometriosis; Hx, history; n, sample size; USL, uterosacral ligaments.

Table 5: Interobserver agreement and Gwet AC_1 Statistics for ultrasound diagnosis based on ultrasound findings of endometriosis of the USL across 6 observers.

	% Agreement	Gwet AC_1 (95% CI)
Overall	72	0.63 (0.53–0.74)
Patients with no clinical DE	75	0.66 (0.39–0.93)
Patients with known DE	72	0.56 (0.36–0.76)

AC_1, agreement coefficient; CI, confidence interval; USL, uterosacral ligaments.

Table 6: Intraobserver agreement and Gwet AC_1 Statistics for ultrasound characteristics of USL across 6 observers.

	Years of experience	% Agreement	Gwet AC_1 (95% CI)
Observer A	14	84	0.80 (0.78–0.90)
Observer B	7	89	0.87 (0.81–0.92)
Observer C	2	79	0.76 (0.69–0.82)
Observer D	4.5	78	0.74 (0.67–0.81)
Observer E	11	69	0.60 (0.52–0.68)
Observer F	16	96	0.96 (0.93–0.99)

AC_1, agreement coefficient; CI, confidence interval; USL, uterosacral ligaments.

(0.60) to almost perfect (0.96). One observer had a moderate agreement (0.60), which was just 0.01 below the threshold for substantial agreement. Three observers had substantial agreements (0.74, 0.76 and 0.80), and two had almost perfect agreements (0.87 and 0.96). These results also indicated that years of experience did not significantly influence intraobserver reliability.

USL measurement agreement and correlation

Moderate interobserver agreement (0.47) was observed for USL thickness (Table 4). For patients with no DE, there was almost perfect agreement (0.86) in identifying thin USLs, while for patients with DE, the agreement dropped to moderate (0.42). Discrepancy also existed in determining where to measure the USL, with a fair agreement (0.29). As shown in Table 7, 92% of observers correctly identified the USL as thin in patients with no history of DE, but there was more variation in identifying thickened USLs in patients with DE (69%).

The correlation between USL thickness and the presence of endometriosis showed a strong positive relationship, which was statistically significant ($r = 0.7965$, $P < 0.01$), as illustrated in the box plot (Figure 5).

Discussion

Inter- and intraobservational agreement

The results of this study have addressed the objectives and demonstrated high intra- and interobservational reproducibility of TVS in assessing the ultrasound characteristics of USLs for diagnosing DE. These findings align with the current systematic review,[24] which, although unvalidated, also reported good consensus on USL characteristics in the literature.

Table 7: Percentage of thin' and 'thick' rated USLs across six observers.

	Patients with no clinical DE (n = 12)		Patients with known DE (n = 30)	
	Thin	% identified thin for normal	Thick	% identified thick for abnormal
Observer A	12/12	100	11/30	36
Observer B	11/12	92	22/30	73
Observer C	9/12	75	29/30	97
Observer D	11/12	92	16/30	73
Observer E	11/12	92	22/30	73
Observer F	12/12	100	25/30	83
Overall	66/72	92	125/180	69

DE, deep endometriosis; n, sample size; USL, uterosacral ligaments.

© 2025 The Author(s). *Australasian Journal of Ultrasound in Medicine* published by John Wiley & Sons Australia, Ltd on behalf of Australasian Society for Ultrasound in Medicine.

22050140, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ajum.12420 by National Health And Medical Research Council, Wiley Online Library on [18/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

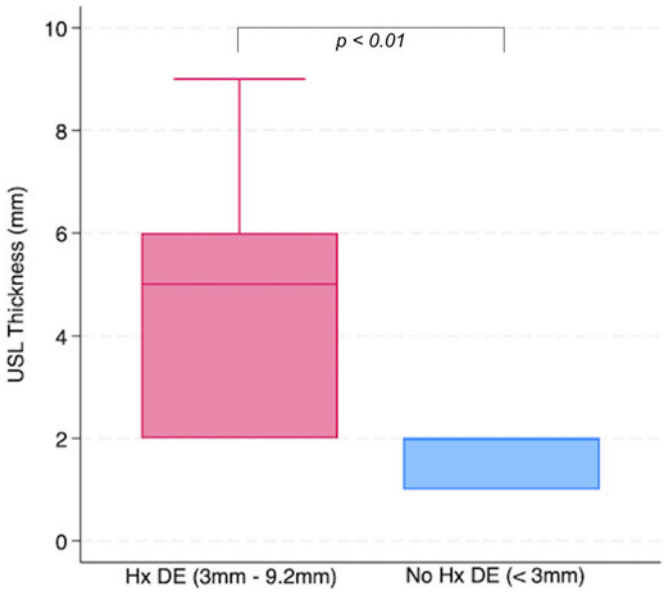


Figure 5: Box plot demonstrating a strong correlation of USL thickness vs. patient endometriosis history. DE, deep endometriosis; Hx, history; mm, millimetres; USL, uterosacral ligaments.

The interobserver agreement for ultrasound diagnosis of endometriosis showed substantial agreement (0.63), with higher agreement for identifying normal USLs (0.66) compared with abnormal USLs (0.56). This suggests that observers had a clear understanding of normal USL appearance but showed some variability in identifying abnormal features. For instance, there was almost perfect agreement on echogenicity (0.96), indicating identifiable diagnostic criteria for assessing USLs. However, there was only moderate reliability for USL contour and thickness, which aligns with previous studies suggesting that USL thickness has poor sensitivity for detecting endometriosis.[30] This highlights the need for further education in this area.

Interobserver agreement on the presence of nodules demonstrated substantial agreement (0.61), indicating that, even with limited criteria, observers can reliably identify DE nodules in the USLs and posterior pelvic compartment. This ability aids both diagnosis and treatment planning, contributing to better patient outcomes, particularly since nodules at the torus uterinus (TU) are frequently affected, with 95.7% of bilateral USL DE cases showing TU plaques.[15] While DE nodules typically occur in the cervical aspect of the USL near the TU insertion[21] (Figure 6a), they can also affect multiple anatomical sites[24] (Figure 6b) and may infiltrate the parametrium[34,35] (Figure 6c). This infiltration is often associated with ovarian adhesion, a common cause of medialised ovaries, especially in the presence of endometriomas[21] (Figure 6a,b), contributing to higher symptomatic pain, as well as tenderness during TVS examination.[36]

Correctly identifying disease extension, such as infiltration into adjacent structures, is essential for planning more complex surgery.[13,35] Endometriosis in these areas can distort anatomy, particularly when the pouch of Douglas (POD) is obliterated,[4] and increase the risk of ureteral involvement.[35] Furthermore, isolated USL endometriotic lesions are common in patients under the age of 25 with severe dysmenorrhea and are often overlooked at laparoscopy.[37] This underscores the importance of pre-surgical planning, as excision of USL DE often requires advanced laparoscopic skills, especially in cases involving an obliterated POD.[4,13] Meaning, sonographer application of the findings of this study may have important clinical implications.

Intraobserver results showed strong agreement, with two observers achieving almost perfect agreement and three others showing substantial agreement. These findings further support the idea that USL characteristics change with DE infiltration and that thickening of the USL is suggestive of endometriosis. These changes can be consistently identified by trained professionals across various disciplines and experience levels, provided the criteria are clear. Once reproducible guidelines and departmental protocols are established, along with targeted sonographer education, further research is needed in general settings to assess whether this approach can improve diagnostic accuracy and facilitate earlier diagnosis.

Measurement correlation

Although taking measurements of the USLs is recommended by the IDEA[9] consensus, the normal thickness of USLs is currently unknown and the standard anatomic plane for reproducible measurements for USLs is not validated.[24] This study found that the subjective thickness for taking measurements of the USLs were the most ambiguous with observers' identification of the thickness of the USL most difficult, with moderate interobserver agreement (0.47), particularly for patients with a history of DE. There was further discrepancy in agreement of where to measure the USL with a fair (0.29) agreement. The observers were asked to annotate freely in a text box as to where they would measure the USL. Generally, the consensus was to measure at the cervical insertion if the USL appeared normal, and to measure the thickest part or at the nodule if the USL was showing signs of DE although agreement was inconsistent.

Patient data, as seen on Table 3, highlighted those patients who had no evidence of DE had USLs all <3 mm, while those patients with known DE had USL measurements ranging from 3.4 mm to 9.2 mm (mean 4.5 mm). Observers identified USLs <3 mm as thin 92% of the time and >3 mm as thickened 69% of the time (Table 7). This indicates that USL thickness can serve as a subjective marker for DE. The strong correlation between USL thickness and DE further supports its potential clinical value for early detection, provided reproducible and validated measurement criteria are established.

Strengths, limitations and future studies

This study is the first to assess the reproducibility of ultrasound criteria for USLs in the diagnosis of endometriosis, testing the applicability of the IDEA[9] consensus and findings from

© 2025 The Author(s). *Australasian Journal of Ultrasound in Medicine* published by John Wiley & Sons Australia, Ltd on behalf of Australasian Society for Ultrasound in Medicine.

22050140, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ajum.12420 by National Health And Medical Research Council, Wiley Online Library on [18/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

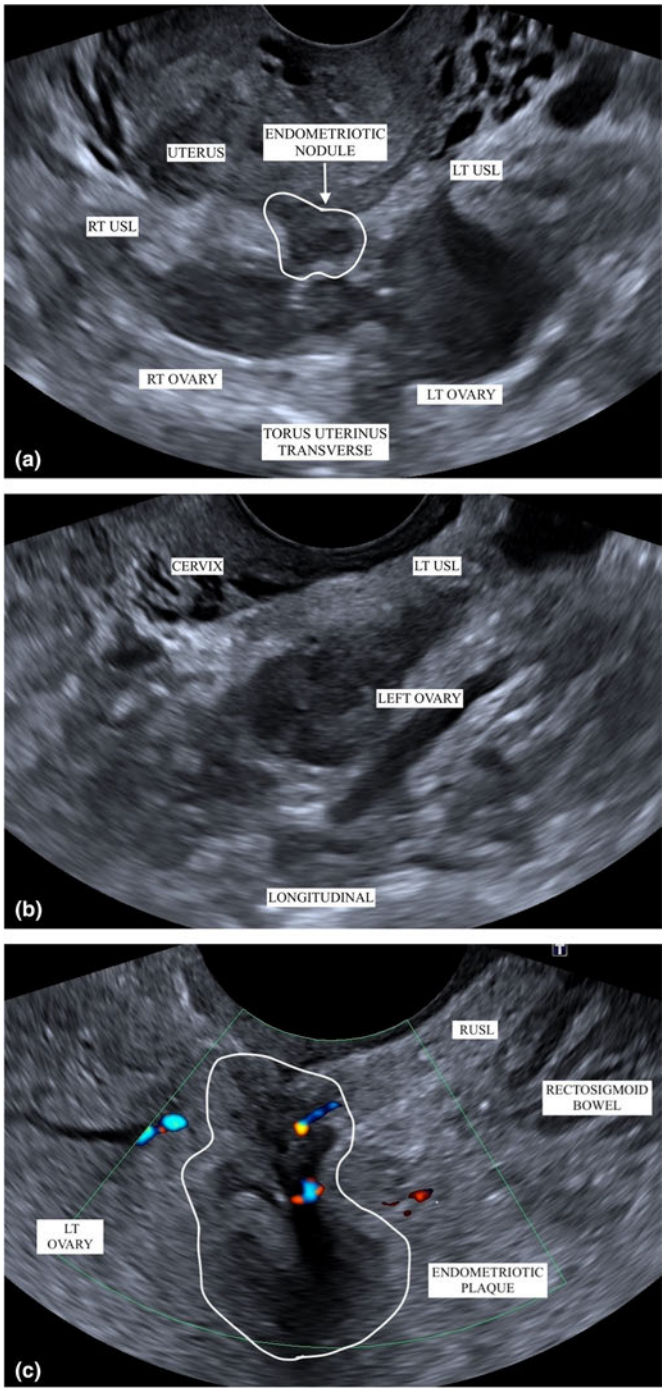


Figure 6: Laparoscopy diagnosed endometriosis with TVS appearances of DE. (a) Transverse plane of bilateral ovarian endometrioma with medialisation of both ovaries adherent to the USLs and the uterine fundus. There is the appearance of an endometriotic nodule at the TU involving both USLs. (b) The LUSLs demonstrated longitudinally is seen thickened, heterogeneous and irregular with the left ovaried adhered. (c) Frozen pelvis, with extensive deep infiltrative endometriosis where the patient report focal sharp pain during sonopalpation. There is endometriosis plaque around the level of the rectosigmoid bowel with appears tethered to the inferior margin of the ovaries, cervix and extends to the right USL with tethering. DE, deep endometriosis; TU, torus uterinus; TVS, transvaginal ultrasound; USL, uterosacral ligaments.

systematic reviews[24] in general, non-specialist clinical settings. While previous studies have examined interobserver variability in ultrasound diagnosis of endometriosis, they have all been conducted in tertiary, specialist settings.[14,38]

Strengths of this study include achieving the required sample size for a well-powered analysis, a prospective design, examiner blinding, a multidisciplinary approach and the fact that all assessments were performed at a single centre. Images were collected by one sonographer using real-time ultrasound, and scans were conducted following a rigorous best-practice protocol, further strengthening the study's reliability.

A notable advantage of this study is that observers were not exposed to non-USL pelvic structures, thereby minimising potential confounders, such as endometriomas, during TVS assessments. However, a limitation lies in the lack of blinding for the sonographer performing the scans, as they were aware of other pelvic pathologies, introducing the risk of confirmation bias. Ideally, future studies aiming to evaluate USL findings should isolate their assessment, independent of broader pelvic or endometriosis evaluations, to eliminate such bias.

In addition to this, further limitations must be considered. The study focused solely on TVS appearances of USLs, and for patients who underwent laparoscopic excision of endometriosis, it is unknown whether USL excision was performed. Given that the USL is a common site for endometriosis and diagnostic surgeries, it is likely that some cases involved surgical intervention, potentially altering USL appearance, which may have impacted the sonographic findings. This represents a significant limitation, as there is uncertainty around whether all measured USLs were from native tissue or if they had been altered post-surgically. Furthermore, it is unclear which USLs may have changed in appearance due to surgery, as this information was not available, thus making it difficult to interpret whether these changes affected the results. Additionally, the study included six observers to assess interrater agreement, and the use of offline images and videos may introduce bias related to the relevance of operator experience. Future studies should involve both novices and experts performing the scans after receiving clear criteria, education and training, and then compare the performance of novices with that of experts to assess the feasibility and effectiveness of this approach. However, ethical and logistical considerations may pose challenges to implementing this design.

© 2025 The Author(s). *Australasian Journal of Ultrasound in Medicine* published by John Wiley & Sons Australia, Ltd on behalf of Australasian Society for Ultrasound in Medicine.

22050140, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ajum.12420 by National Health And Medical Research Council, Wiley Online Library on [18/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Despite these limitations, this study demonstrates significant interobserver reliability, potentially laying the groundwork for future studies that validate the findings discussed in this study including TVS diagnostic characteristics of USL DE, improved understanding of normal and abnormal USLs. Further research is needed to establish reliable cut-offs for USL thickness and to determine its clinical relevance. Additionally, studies should explore the impact of implementing the IDEA[9] consensus and rigorous scanning protocols in general clinical settings, as well as the need for updated and standardised scanning protocols in general ultrasound departments. Lastly, further investigation is required to assess the reproducibility of TVS USL examination in general settings and whether additional training is necessary for sonographers and radiologists.

Conclusion

This study demonstrates high inter- and intraobserver agreement among sonographers and imaging professionals in a general imaging department for identifying ultrasound characteristics of USLs and diagnosing DE using TVS, when current recommended guidelines are followed. It confirms that TVS is a reliable tool across both experienced and less experienced examiners in general imaging settings and shows that trained professionals can consistently identify key USL characteristics, including echogenicity, thickness and nodules, thereby supporting the use of TVS in general imaging for detecting USL DE.

Notably, there was strong agreement in identifying abnormal USLs, particularly in detecting nodules, while agreement on USL thickness and measurement site was more variable. The study also found a strong positive correlation between USL thickness and the presence of DE. However, there is no consensus on the optimal site for measuring the USL. Despite this, incorporating USL examination into routine pelvic scans may be helpful for detecting thickening, which could prompt further investigation for other endometriosis markers. This approach is valuable especially in general imaging settings, where skill levels may vary, as identifying these markers can help facilitate referral to a specialist centre, as recommended by the IDEA[9] consensus.

While reproducible measurement criteria and sonographer education are necessary, the results suggest that TVS, when applied with clear criteria, could improve early diagnosis and treatment planning for endometriosis. This research contributes to the growing body of evidence supporting the clinical value of TVS in endometriosis management, offering insights into how sonographers can play a crucial role in early detection and improved patient outcomes.

Author Contributions

Shae Maple: Conceptualization; methodology; validation; formal analysis; investigation; resources; data curation; writing – original draft preparation; writing – review and editing; supervision; project administration. **Eva Bezak:** Conceptualization; methodology; validation; formal analysis; investigation; writing – review and editing; supervision; project administration. **K Jane Chalmers:** Conceptualization; methodology; supervision; project administration. **Nayana Parange:** Conceptualization; methodology; validation; formal analysis; investigation; writing – review and editing; supervision; project administration. All authors have read and agreed to the published version of the manuscript.

Acknowledgements

We gratefully acknowledge Adrian Esterman for his assistance with the statistical analysis. Open access publishing facilitated by University of South Australia, as part of the Wiley - University of South Australia agreement via the Council of Australian University Librarians.

Funding

This research received no external funding.

Conflict of interest

The authors declare no conflict of interest.

Disclosure statement

Nayana Parange is an associate editor for AJUM. This research is supported by The University of South Australia.

Data availability statement

The data presented in this study are available upon request from the corresponding author due to patient confidentiality restrictions.

References

1 Zondervan KT, Becker CM, Koga K, Missmer SA, Taylor RN, Viganò P. Endometriosis. *Nat Rev Dis Primers* 2018; 4(1): 9.
2 Bazot M, Thomassin I, Hourani R, Cortez A, Darai E. Diagnostic accuracy of transvaginal sonography for deep pelvic endometriosis. *Ultrasound Obstet Gynecol* 2004; 24(2): 180–5.
3 Scioscia M, Scardapane A, Virgilio BA, Libera M, Lorusso F, Noventa M. Ultrasound of the uterosacral ligament, parametrium, and paracervix: disagreement in terminology between imaging anatomy and modern gynecologic surgery. *Aust Dent J* 2021; 10(3): 1–11.
4 Leonardi M, Condous G. A pictorial guide to the ultrasound identification and assessment of uterosacral ligaments in women with potential endometriosis. *Australas J Ultrasound Med* 2019; 22(3): 157–64.
5 O'Hara R, Rowe H, Fisher J. Managing endometriosis: a cross-sectional survey of women in Australia. *J Psychosom Obstet Gynaecol.* 2020; 43(3): 265–72.
6 Zhou Y, Su Y, Liu H, Wu H, Xu J, Dong F. Accuracy of transvaginal ultrasound for diagnosis of deep infiltrating endometriosis in the uterosacral ligaments: systematic review and meta-analysis. *J Gynecol Obstet Hum Reprod* 2021; 50(3): 101953.
7 Bazot M, Lafont C, Rouzier R, Roseau G, Thomassin-Naggara I, Darai E. Diagnostic accuracy of physical examination, transvaginal sonography, rectal endoscopic sonography, and magnetic resonance imaging to diagnose deep infiltrating endometriosis. *Fertil Steril* 2009; 92(6): 1825–33.

© 2025 The Author(s). *Australasian Journal of Ultrasound in Medicine* published by John Wiley & Sons Australia, Ltd on behalf of Australasian Society for Ultrasound in Medicine.

22050140, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ajum.12420 by National Health And Medical Research Council, Wiley Online Library on [18/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

8 Vu D, Haylen B, Tse K, Farnsworth A. Surgical anatomy of the uterosacral ligament. *Int Urogynecol J* 2010; 21: 1123–8.
9 Guerriero S, Condous G, van den Bosch T, Valentin L, Leone FPG, van Schoubroeck D, *et al*. Systematic approach to sonographic evaluation of the pelvis in women with suspected endometriosis, including terms, definitions and measurements: a consensus opinion from the international deep endometriosis analysis (IDEA) group. *Ultrasound Obstet Gynecol* 2016; 48(3): 318–32.
10 Becker CM, Bokor A, Heikinheimo O, Horne A, Jansen F, Kiesel L, *et al*. ESHRE guideline: endometriosis. *Hum Reprod Open* 2022; 2022(2): hoac009.
11 RANZCOG. Australian clinical practice guideline for the diagnosis and management of endometriosis. 2021. Royal Australian and New Zealand College of Obstetrics and Gynaecology, Melbourne, Australia.
12 ACOG. The American College of Obstetricians and Gynecologists - practice bulletin no. 114: management of endometriosis. *Obstet Gynecol* 2010; 116(1): 223–36.
13 Pascoal E, Wessels JM, Aas-Eng MK, Abrao MS, Condous G, Jurkovic D, *et al*. Strengths and limitations of diagnostic tools for endometriosis and relevance in diagnostic test accuracy research. *Ultrasound Obstet Gynecol* 2022; 60: 309–27.
14 Tammaa A, Fritzer N, Lozano P, Krell A, Salzer H, Salama M, *et al*. Interobserver agreement and accuracy of non-invasive diagnosis of endometriosis by transvaginal sonography. *Ultrasound Obstet Gynecol* 2015; 46(6): 737–40.
15 El-Maadawy SM, Alaaeldin N, Nagy CB. Role of preoperative ultrasound mapping in the surgical management of deep infiltrating endometriosis: a prospective observational study. *Egypt J Radiol Nucl Med* 2021; 52: 159.
16 Hudelist G, Oberwinkler KH, Singer CF, Tuttlies F, Rauter G, Ritter O, *et al*. Combination of transvaginal sonography and clinical examination for preoperative diagnosis of pelvic endometriosis. *Hum Reprod* 2009; 24(5): 1018–24.
17 Yin S, Lin Q, Xu F, Xu J, Zhang Y. Diagnosis of deep infiltrating endometriosis using transvaginal ultrasonography. *Front Med (Lausanne)* 2020; 7: 567929.
18 Abrao MS, Gonçalves MO, Dias JA Jr, Podgaec S, Chamie LP, Blasbalg R. Comparison between clinical examination, transvaginal sonography and magnetic resonance imaging for the diagnosis of deep endometriosis. *Hum Reprod* 2007; 22(12): 3092–7.
19 Freger SM, Turnbull V, McGowan K, Leonardi M. Prospective diagnostic test accuracy of transvaginal ultrasound posterior approach for uterosacral ligament and torus uterinus deep endometriosis. *Ultrasound Obstet Gynecol* 2024; 63(2): 263–70.
20 Deslandes A, Panuccio C, Avery J, Condous G, Leonardi M, Knox S, *et al*. Are sonographers the future 'gold standard' in the diagnosis of endometriosis? *Sonography* 2023; 11: 278–86.
21 Young SW, Jha P, Chamié L, Rodgers S, Kho RM, Horrow MM, *et al*. Society of radiologists in ultrasound consensus on routine pelvic US for endometriosis. *Radiology* 2024; 311(1): e232191.
22 Chaggar P, Tellum T, Cohen A, Jurkovic D. Intra- and interobserver reproducibility of transvaginal ultrasound for the detection and measurement of endometriotic lesions of the bowel. *Acta Obstet Gynecol Scand* 2023; 102(10): 1306–15.
23 Reid S, Casikar I, Condous G. The use of the transvaginal ultrasound in the prediction of pouch of douglas obliteration in women with suspected endometriosis. In: Juarez M, Tomas L, editors. Endometriosis: risk factors, symptoms and management. New York, NY: Nova Science Publishers; 2013. 227–40.
24 Maple S, Chalmers KJ, Bezak E, Henry K, Parange N. Ultrasound characteristics and scanning techniques of uterosacral ligaments for the diagnosis of endometriosis. *J Ultrasound Med* 2022; 42(6): 1193–209.
25 Kamkarfar P, Shahriyaripoor R, Rokhgireh S, Saadat Mostafavi SR, Chaichian S, Mehdizadeh KA. Comparison of diagnostic values of transvaginal sonography with laparoscopic and histological results in the evaluation of uterosacral ligaments' involvement in endometriosis patients. *Caspian J Intern Med* 2022; 13(4): 705–12.
26 Kottner J, Audige L, Brorson S, Donner A, Gajewski BJ, Hróbjartsson A, *et al*. Guidelines for reporting reliability and agreement studies (GRRAS) were proposed. *Int J Nurs Stud* 2011; 48(6): 661–71.
27 Faul F. G*power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods* 2007; 39(2): 175–91.
28 Australasian Society for Ultrasound in Medicine (ASUM). Guidelines on the performance of a gynaecological ultrasound examination. https://www.asum.com.au/files/public/SoP/curver/Obs-Gynae/Gynaecological-GL-2020.pdf.
29 Leonardi M, Condous G. How to perform an ultrasound to diagnose endometriosis. *Australas J Ultrasound Med* 2018; 21(2): 61–9.
30 Robinson AJ, Rombauts L, Ades A, Leong K, Paul E, Piessens S. Poor sensitivity of transvaginal ultrasound markers in diagnosis of superficial endometriosis of the uterosacral ligaments. *J Endometr Pelvic Pain Disord* 2018; 10(1): 10–7.
31 Chowdary P, Stone K, Ma T, Readman E, McIlwaine K, Druitt M, *et al*. Multicentre retrospective study to assess diagnostic accuracy of ultrasound for superficial endometriosis-are we any closer? *Aust N Z J Obstet Gynaecol* 2019; 59(2): 279–84.
32 StataCorp. Stata statistical software: release 18. College Station, TX: StataCorp LLC; 2023.
33 Allaire C, Bedaiwy MA, Yong PJ. Diagnosis and management of endometriosis. *CMAJ* 2023; 195(10): E363–71.
34 Daniilidis A, Grigoriadis G, Dalakoura D, D'Alterio MN, Angioni S, Roman H. Transvaginal ultrasound in the diagnosis and assessment of endometriosis-an overview: how, why, and when. *Diagnostics (Basel)* 2022; 12(12): 2912.
35 Leonardi M, Martins WP, Espada M, Arianayagam M, Condous G. Proposed technique to visualize and classify uterosacral ligament deep endometriosis with and without infiltration into parametrium or torus uterinus. *Ultrasound Obstet Gynecol* 2020; 55(1): 137–9.
36 Maple S, Bezak E, Chalmers KJ, Parange N. Relationship between ultrasound diagnosis, symptoms and pain scale score on examination in patients with uterosacral ligament endometriosis. *Aust Dent J* 2024; 13(22): 6901.
37 Martire FG, Russo C, Selntigia A, Nocita E, Soreca G, Lazzeri L, *et al*. Early noninvasive diagnosis of endometriosis: dysmenorrhea and specific ultrasound findings are important indicators in young women. *Fertil Steril* 2023; 119(3): 455–64.
38 Reid S, Lu C, Casikar I, Mein B, Magotti R, Ludlow J, *et al*. The prediction of pouch of Douglas obliteration using offline analysis of the transvaginal ultrasound 'sliding sign' technique: inter- and intra-observer reproducibility. *Hum Reprod* 2013; 28(5): 1237–46.

© 2025 The Author(s). *Australasian Journal of Ultrasound in Medicine* published by John Wiley & Sons Australia, Ltd on behalf of Australasian Society for Ultrasound in Medicine.

22050140, 2025, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/ajum.12420 by National Health And Medical Research Council, Wiley Online Library on [18/02/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

3.3 Discussion and Conclusion

3.3.1 Key Findings

Six professionals (five sonographers and one radiologist) with varying levels of experience (2–16 years) reviewed 42 patient images of the USLs across two sessions. The intra and interoperator reliability of TVS characteristics for normal and abnormal USLs was calculated.

Intraobserver agreement among the reviewers ranged from moderate (0.60) to almost perfect (0.96), indicating that years of experience were not a significant factor in intrarater reliability. Interobserver agreement for the seven USL characteristics was substantial (0.65). Individual USL characteristics demonstrated a range of agreement from moderate to almost perfect among the observers.

Since there is no definitive standard for ultrasound diagnosis of USL DE[68], previous studies were used as a guide[78]. USLs were classified as thickened if their thickness exceeded 3 mm[79], with measurements greater than 5 mm[1] suggesting more significant disease involvement. However, there was inconsistency in determining the exact location for measuring USL thickness, with only fair agreement (0.28) on measurement sites.

Despite this, observers reliably identified USLs less than 3 mm as thin in 92% of cases and those greater than 3 mm as thickened in 69% of cases. This demonstrates that USL thickness exceeding 3 mm can be reliably identified and used as a marker for endometriosis. The strong correlation ($r = 0.7965$) between USL thickness and DE further supports this finding.

3.3.2 Novel Contribution to Literature

This study is the first to evaluate intra and interobserver agreement for TVS characteristics of USLs in predicting endometriosis, specifically testing the applicability of the IDEA[22] consensus in non-specialist settings. It demonstrates consistency in identifying thickened USLs while highlighting the lack of consensus on the optimal measurement site.

The findings suggest that radiologists and sonographers can integrate TVS of USLs into their routine skill set. Including USL examination in routine pelvic scans could help

identify thickened USLs, prompting further investigation for other markers of endometriosis, even in general imaging clinics.

3.3.3 Strengths and Limitations

This study adhered to the Guidelines for Reporting Reliability and Agreement Studies (GRRAS)[80], ensuring high methodological quality and reproducibility.

However, several limitations should be considered:

1. The sonographer performing the scans was not blinded to other pelvic pathologies, introducing the potential for confirmation bias.
2. The study focused solely on TVS appearances of USLs without determining whether laparoscopic excision of endometriosis had been performed. This makes it unclear if the observed USLs were native or altered post-surgically, potentially impacting the results.
3. The use of offline images and videos for interobserver assessments, which may have introduced biases related to operator experience. Reviewing offline images does not fully replicate the dynamic assessment performed during real-time sonography. To overcome this, a combination of still images and video cine loops was provided, but this approach may not entirely reflect clinical practice.

Future studies should address these limitations by incorporating larger sample sizes, blinding sonographers to clinical findings, and including real-time scanning to improve the reliability and applicability of findings.

Chapter 4

Relationship Between Ultrasound Diagnosis, Symptoms and Pain Scale Score on Examination in Patients with Uterosacral Ligament Endometriosis

The published article (Maple et al., 2024)[70] forms the basis of this chapter.

Maple S, Bezak E, Chalmers KJ, Parange N. (2024), ***Relationship Between Ultrasound Diagnosis, Symptoms and Pain Scale Score on Examination in Patients with Uterosacral Ligament Endometriosis.*** *Journal of Clinical Medicine*; 13(22):6901. https://doi.org/10.3390/jcm13226901

4.1 Introduction and Motivation

Previous chapters established agreement on the ultrasound characteristics of the USLs for diagnosing DE using current guidelines. They also demonstrated that both experienced and inexperienced operators can achieve comparable results in ultrasound assessments of the USLs.

This study expands upon the established diagnostic criteria for USLs by incorporating site-specific tenderness and pain scale descriptors into TVS evaluations for DE. The

objective is to assess whether these additions enhance diagnostic accuracy, particularly in clinics where expertise in endometriosis diagnostics is limited.

This chapter presents a prospective observational cohort study of 42 women who underwent TVS for suspected endometriosis. The study aims to evaluate the role of patient pain descriptors in diagnosing USL endometriosis and to determine whether including SST pain score information influences diagnostic decisions made by imaging professionals.

4.2 Published Journal Article

Pages 91-105 contain the research paper by Maple et al., (2024)[70] as published in *The Journal of Clinical Medicine (JCM)*, November 2024.

Journal of
Clinical Medicine

MDPI

Article

Relationship Between Ultrasound Diagnosis, Symptoms and Pain Scale Score on Examination in Patients with Uterosacral Ligament Endometriosis

Shae Maple *, Eva Bezak, K. Jane Chalmers and Nayana Parange

Allied Health and Human Performance, University of South Australia, GPO Box 2471, Adelaide, SA 5001, Australia
* Correspondence: shae.maple@unisa.edu.au

Abstract: Background/Objectives: This study investigated patient pain descriptors for transvaginal ultrasound (TVS) diagnostic evaluation of endometriosis for uterosacral ligaments (USLs), including correlation between USL thickness and site-specific tenderness (SST). It further investigated if SST could positively assist diagnosing endometriosis on TVS. **Methods:** TVS images and SST pain descriptors were collected from 42 patients. SST was evaluated by applying sonopalpation during TVS. The images were presented to six observers for diagnosis based on established USL criteria. Following this, they were given the SST pain scores and asked to reevaluate their diagnosis to assess if the pain scores impacted their decision. **Results:** An independent *t*-test showed that the patients with an endometriosis history had higher pain scores overall (7.2 ± 0.59) compared to the patients with no history (0.34 ± 0.12), t (40) = 8.8673. Spearman's correlation showed a strong correlation to the pain scale score for clinical symptoms ($r = 0.74$), endometriosis diagnosis ($r = 0.78$), USL thickness ($r = 0.74$), and when USL nodules were identified ($r = 0.70$). Paired *t*-tests showed that the observers demonstrated a higher ability to correctly identify endometriosis with the pain scale information (33 ± 8.83) as opposed to not having this information (29.67 ± 6.31), which was a statistically significant change of 3.33, t (5) = 2.7735. **Conclusions:** Patients with an endometriosis history have significantly higher pain scores on TVS compared to patients with no endometriosis history. A strong correlation was shown between SST pain scores and patient symptoms, USL thickness, and USL nodules. Inclusion of SST alongside TVS imaging shows promise, with these results demonstrating a higher ability to diagnose endometriosis with additional SST pain scale information.

Keywords: deep infiltrating endometriosis; gynecology; sonography; site-specific tenderness; transvaginal ultrasound; uterosacral ligaments

check for updates

Citation: Maple, S.; Bezak, E.; Chalmers, K.J.; Parange, N. Relationship Between Ultrasound Diagnosis, Symptoms and Pain Scale Score on Examination in Patients with Uterosacral Ligament Endometriosis. *J. Clin. Med.* **2024**, *13*, 6901. https://doi.org/10.3390/jcm13226901

Academic Editor: Errico Zupi

Received: 3 October 2024
Revised: 9 November 2024
Accepted: 13 November 2024
Published: 16 November 2024

Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Endometriosis occurs when endometrial-like tissue extends outside of the uterine cavity [1], with the subtype of deep endometriosis (DE) occurring when endometriotic tissue infiltrates >5 mm under the peritoneum [2–5]. So far, the mechanisms of endometriosis have not been fully agreed upon, but endometriosis is considered a chronic inflammatory process associated with immune processes [3] that results in fibrosis and organ immobility [6] that cause chronic pelvic pain [1,3,6]. This impacts physical and mental health, as well as the social well-being of the patient, due to a significant deterioration in the quality of life [3]. It is estimated that endometriosis affects 10% of female-born people [1]; however, the true frequency of endometriosis is uncertain, because a definitive diagnosis requires laparoscopy and histopathology, which is not always accessible. With the new acknowledgment that transvaginal ultrasound (TVS) is capable of and accurate in detecting endometriosis and with the current recognition of diagnostic delays, as well as the invasiveness, cost, and post-surgical recovery time of surgery, the European Society of Human Reproduction and Embryology (2022) guidelines [7] now recommend the use of TVS as the first-line imaging tool for endometriosis.

In 2016, the International Deep Endometriosis Analysis group (IDEA) [8] developed the first guidelines for reproducible sonographic features of endometriosis, with TVS now demonstrating reliable accuracy for diagnosing DE [9]. The most current International Consensus Statement (2024) [10] advises that (a) "TVS performed by adequately trained operators is recommended as the first-line imaging tool" [10] and (b) "imaging with TVS can help to preoperatively predict the presence of DE of the USLs" [10], although ongoing research is still needed to support this statement. As such, diagnosis of DE of the uterosacral ligaments (USLs) remains the most difficult [10–13]. Studies have shown improvements by implementing the standardized posterior approach [14], providing evidence that with refinement of these techniques and ultrasound criteria, diagnostic ability can continue to improve [15,16].

Broadly speaking, endometriosis has a wide range of symptoms, including chronic pelvic pain [2,17], dysmenorrhea [2,5,18–22], dyspareunia [18,20,22–26], and/or infertility [6,14]. However, the relationship between the type and site of the endometriotic lesions and the severity of pelvic symptoms is a matter of debate, as data from numerous studies on such relationships are contradictory [18]. There has been, however, a strong association observed in several studies between deep posterior compartment DE deposits and dyspareunia [18,20,22–25].

USLs sit in this posterior compartment and can be easily visualized with TVS [10,12]. USLs are also one of the most common sites of DE [4,6,10,14,27], as the distal section attaches to the posterior cervix at the torus uterinus (TU) [8,14,28]. This anatomical location allows USLs to also be associated with rectal DE [6,15] and adhesions to the ovary in the presence of an endometrioma, often visualized with one or both ovaries located posteriorly at the TU, all contributing to dyspareunia and pelvic pain [6,29,30]. Therefore, there is some benefit in including tenderness-directed TVS scanning [31].

These pain symptoms associated with endometriosis can be replicated by site-specific tenderness (SST) ultrasound scanning by using gentle transductor pressure. Pain scale tests can be used to measure SST and provide valuable information on the specific pain experienced by endometriosis sufferers [32]. Incorporating SST over the USLs and the relationship with endometriosis is a valuable component of the TVS examination, providing beneficial insight into the extent of endometriosis [33], as well as reliably assisting in the diagnosis of posterior compartment DE [34–36]. Recent reviews [12] have determined that more refinement is still needed for incorporating SST to assist in diagnosing DE, as current literature has little guidance on pain scale correlation of USL changes in the diagnosis of DE, such as using a visual analogue or numerical rating scale to capture the severity of pain during TVS [12]. Without this information, it is difficult to determine the correlation of SST with endometriotic nodules and therefore difficult to determine the true value of SST-TVS of the USLs.

In this light, the aim of this study was to evaluate patient pain descriptors in the ultrasound diagnostic evaluation of endometriosis of the uterosacral ligaments and investigate if SST descriptors can positively assist in diagnosing endometriosis on TVS.

2. Methods

2.1. Study Design and Ethics

This observational cohort study was conducted between November 2021 and September 2022. Methodology followed the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines [37]. This study was approved by the University of South Australia Human Research Ethics Committee (project number 204278). Written informed consent was obtained from all subjects before the study.

2.2. Study Setting and Patient Participants

Prior to patient recruitment, sample size calculation was performed using G*Power software version 3.1.9.7 [38], which estimated a minimum sample size of 42 patients with

five observers to show significant results with a large effect size of 95%, a power of 0.8, and a 95% confidence interval.

Forty-two (42) patients who met the inclusion criteria (Figure 1) and who presented to an outpatient general imaging private practice in South Australia following a referral from either a general practitioner or a gynecologist from November 2021 until September 2022 were included in this study. Twelve (12) of the patients presented with no history or symptoms of endometriosis, while 30 patients presented with medically diagnosed endometriosis, either via laparoscopy or clinically diagnosed by a gynecologist.

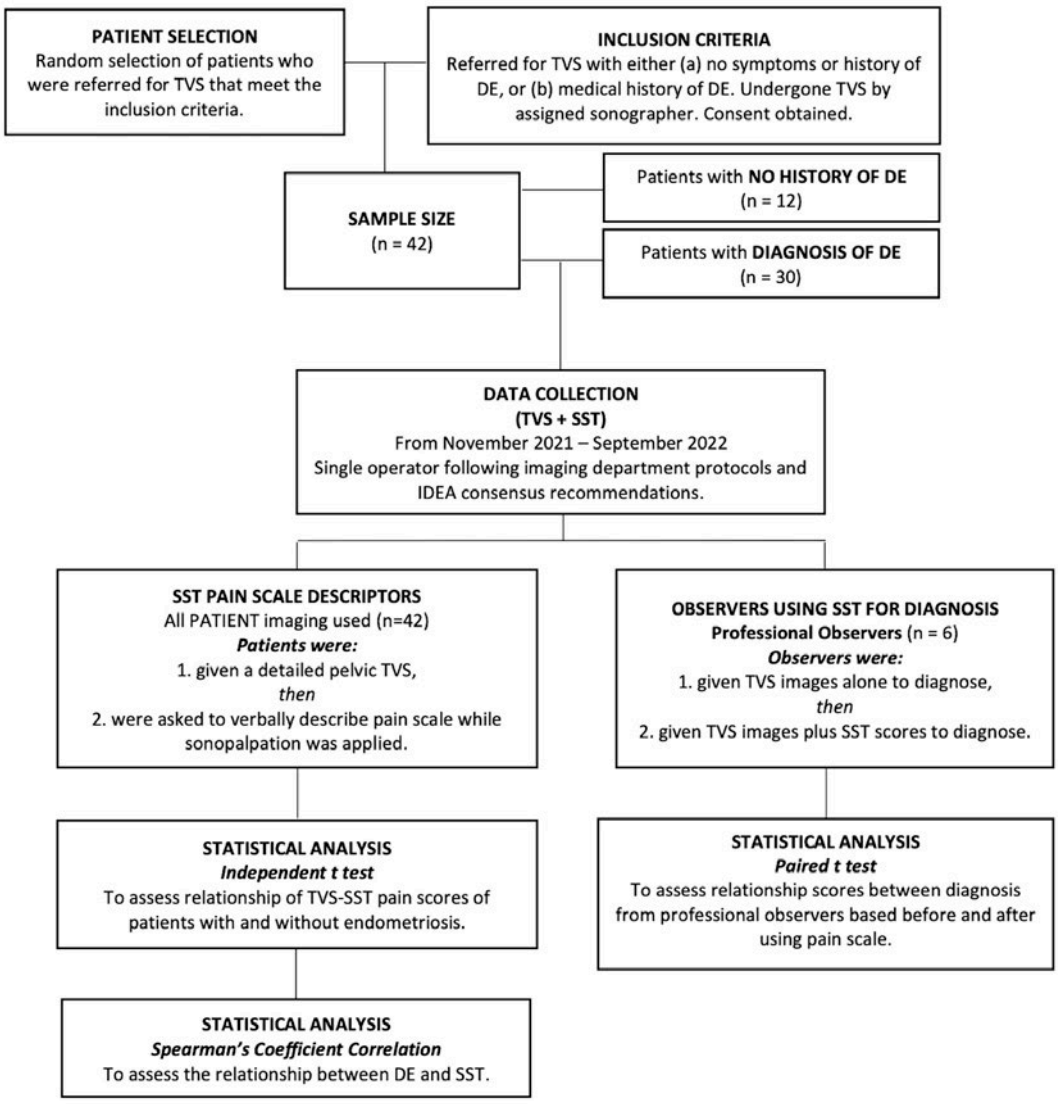


Figure 1. Flowchart summarizing the methodology process and the inclusion criteria of eligible patients and observers in the study. TVS, transvaginal ultrasound, DE, Deep Endometriosis, IDEA, International Deep Endometriosis Analysis, SST, site-specific tenderness.

Detailed TVS for endometriosis was performed, and the patient pain descriptors were collected. Analysis of the ultrasound characteristics of the USLs was performed by six observers, including five Accredited Medical Sonographers as per the Australia Sonographers Accreditation Registry (ASAR) and one Royal Australian and New Zealand College of Obstetricians and Gynaecologists (RANZCOG)-accredited radiologist. A multidisciplinary approach was achieved by selecting observers with different levels of experience and qualifications to reduce professional bias and reflect practice in clinical settings. The detailed process is shown in Figure 1.

2.3. Study Objectives

The first objective was to evaluate the use of patient pain descriptors in the ultrasound diagnostic evaluation of endometriosis, including the correlation between USL thickness and SST. The second objective was to investigate if this additional patient SST pain score information altered the diagnostic decision of endometriosis by imaging professionals when diagnosing endometriosis on TVS.

2.4. Outcome Measures

The ultrasound images were presented to the observers for diagnosis. Following this, they were given the SST pain scores for each patient participant and asked to reevaluate their diagnosis to assess if the pain score impacted their decision.

2.5. Data Sources and Collection

2.5.1. Image Acquisition

To reduce variability in the acquired images, TVS was performed by an experienced accredited sonographer with 15 years' experience using Canon i800, Aplio 500, Aplio a550, and Aplio XG (Canon Medical System Corporation, Otawara, Tochigi, Japan) ultrasound machines with an 11CV3, 11CV, or 9C3 (3–11 MHz) transvaginal transducer.

Assessment of the complete pelvis was performed to include the uterus, cervix, adnexa, and ovaries, as well as the vagina, RVS, urinary bladder, rectosigmoid, and the USLs. Each examination was performed as per the referral request and adhered to general practice imaging protocols congruent with the national Australian Society of Ultrasound in Medicine guidelines [39] and the recommended four-step method outlined within the IDEA consensus [8,40] for the diagnosis of endometriosis.

To ensure consistency and reproducibility, the current recommended ultrasound techniques to visualize the USLs [12,14] were used. This involved placing the transducer into the posterior vaginal fornix and withdrawing it backwards into the vagina. Keeping the transducer in the longitudinal plane, it was then angled inferolaterally to visualize the cervix and then rotated approximately 45° until a hyperechoic line, which is the USL, came into view [12,14]. Findings of endometriosis were diagnosed according to the systematic approach described by the IDEA [8] group.

2.5.2. Assessment of Pain During TVS for Endometriosis

SST was evaluated by applying sonopalpation during TVS. The patients were asked to verbally describe their SST with pain during the scan in line with the validated short-form McGill Pain Scale questionnaire (SF-MPQ) [41,42]. The SF-MPQ comprises two measurement components: the Pain Rating Index (PRI) and the Present Pain Intensity (PPI) visual analogue scale. For *PRI*, the patients were asked to describe what the pain felt like with six qualitative reports of pain: bloating (0), tender (1), dull ache (2), cramping or pressure (3), sharp (4), or stabbing (5). For PPI, the patients were asked "Can you tell me how painful this spot is on a scale of 0–10 where 0 represents no pain and 10 represents the worst pain imaginable". The sum of the sensory and affective components produced the McGill total pain score [32].

2.5.3. Observers

Each observer reviewed the 42 cases of USLs both with and without an endometriosis history. In each case, the reviewed images included a still image of the USL in the longitudinal plane and a video clip demonstrating a sweep through and/or some real-time dynamics of the USL in question. The observers were blinded to the group of patients and each other's responses.

Normal USLs appeared as a smooth linear, hyperechoic, and homogeneous structure that slid freely over the vaginal wall when transducer pressure was applied and released [12]. USLs were considered to have endometriotic involvement when they appeared thickened with some heterogenous changes and/or when there was hypoechoic

linear thickening with regular or irregular margins of the USL. Endometriotic nodules were visualized as a solid hypoechoic nodule with regular, irregular, or stellate margins that were tender on sonopalpation and fixed to the surrounding pelvic structures [12].

The observers were asked to make a diagnosis of endometriosis based on the USL images alone, with a follow-up question where they were given the documented results from the SST evaluation based on the SF-MPQ pain scale grading [32,41,42] to see if the pain scale information influenced their response to the characteristics they were observing. Images and data analysis for this paper were compiled for offline review using Qualtrics software, version XM, June 2023, (Qualtrics, 2023, Provo, UT, USA).

2.6. Statistical Analyses

Descriptive statistics for patient participants' demographics were recorded and collated for analysis. Ultrasound evaluation of the patient pain descriptors for endometriosis was analyzed using independent sample *t*-tests [43] on the sample of 42 patients to determine differences between the SF-MPQ SST pain score grading in patients with endometriosis and those without. SST pain scale (0–15) was calculated as a mean ± SD. Spearman's correlation coefficient [43] was used to determine the relationship between endometriosis characteristics on TVS and SST pain scale grading, where the outcome results were interpreted according to the degree of association as strong (r = 0.7–1), moderate (r = 0.5–0.7), or low (r = 0.3–0.5) after taking significant correlation ($p < 0.01$ or $p < 0.05$) values into consideration. Paired *t*-tests [43] were used on the six professional observer results to determine whether there was a statistically significant relationship between the image interpretation of USLs without pain scale information compared to the image interpretation of USLs with pain scale information. Results were considered statistically significant when $p < 0.05$. Statistical analyses were performed with Stata/SE 18.0 for Mac (Intel 64-bit), revision 4 October 2023 [43].

3. Results

3.1. Patient Participant Characteristics and Ultrasound Data Sets

Forty-two (42) women were included in the study. The mean age was 33.6 (range 18–54) years. Four of the women in our final analysis aged over 50 years had chronic known endometriosis. The presenting symptoms were dysmenorrhea in 16/42 (38.1%), chronic pelvic pain in 26/42 (61.9%), dyspareunia in 5/42 (11.9%), and infertility in 6/42 (14.3%). At laparoscopy, 10/42 (23.8%) women had confirmed endometriosis, 7/42 (16.7%) were clinically diagnosed, while 13/42 (31%) were referred for TVS with clinical suspicion of endometriosis. Table 1 details the findings of endometriosis on ultrasound for the patients with a known or suspected history of endometriosis. Of the 30 women with known endometriosis, 3/30 (10%) women had endometriosis in a single location (excluding USL changes), whilst the remaining 90% had endometriosis in two or more locations. This included focal endometriotic lesions including rectosigmoid, rectocervical, and focal LSCS scar lesions 21/30 (70%), medialized ovaries 9/30 (30%), adherent ovaries 21/30 (70%), endometrioma (14/30 (46.7%), a fixed or rotated uterus 11/30 (36.7%), and obliterated POD 4/30 (13.3%). Also, 19/30 (63.3%) of participants had evidence of adenomyosis.

There was no DE present in any participant who presented with no symptoms or history of DE. Of the 30 participants with known DE, 12 (40%) USL nodules were detected, and all 30 appeared thickened >3 mm. Measurements of the USLs were taken and recorded for all participants.

Table 1. Patient characteristics and findings of TVS of the study cohort (n = 42).

	All Patients (n = 42)		with DE (n = 30)		No DE (n = 12)	
Characteristics	***n***	**%**	***n***	**%**	***n***	**%**
Patient Age (Range 18–54, Mean 33.6)						
<19	3	7.1	2	6.7	1	8.3
20–29	11	26.2	7	23.3	4	33.3
30–39	17	40.5	13	43.3	4	33.3
40–49	7	16.6	6	14.3	1	8.3
>50	4	9.5	2	6.7	2	16.6
Diagnosis	**30**	**71**	**30**	**71**	**12**	**28.6**
DE Diagnosed Laparoscopy	10	24	10	23.8	-	-
DE Diagnosed Clinically	7	17	20	16.7	-	-
DE Clinically Investigated	13	31	13	31	-	-
Indication for TVS						
Chronic Pelvic Pain	26	61.9	26	61.9	-	-
Dysmenorrhea	16	38.1	16	38.1	-	-
Infertility	6	14.3	6	14.3	-	-
Dyspareunia	5	11.9	5	11.9	-	-
Other	12	29	-	-	12	100
Findings of endometriosis on TVS						
Endometriosis present	30	71	30	100	0	0
Endometrioma	14	33.3	14	46.7	-	-
Obliterated POD	4	9.5	4	13.3	-	-
Adherent Ovaries	21	50	21	70.0	-	-
Medialised Ovaries	9	21.4	9	30.0	-	-
Retroverted or Rotated Uterus	11	26.2	11	36.7	-	-
Adenomyosis	19	45.2	19	63.3	-	-
Total Focal Endometriotic Lesions	21	50	21	70.0	-	-
Types of Endometriotic Lesions:						
Rectosigmoid DE	7	16.6	7	23.3	-	-
Rectocervical DE	9	21.4	9	30.0	-	-
USL DE (nodule)	12	28.6	12	40.0	-	-
Vaginal DE	0	0.0	0	0.0	-	-
Bladder DE	0	0.0	0	0.0	-	-
Uterine Serosal Plaques	2	4.8	2	6.7	-	-
LSCS Scar Endometriosis	1	2.4	1	3.3	-	-

KEY: (TVS) transvaginal ultrasound, (POD) Pouch of Douglas, (DE) Deep Endometriosis, (LSCS) Lower section Cesarean section. * "Other" indications for TVS include: bloating, polycystic ovarian syndrome, follow-up for endometrial polyp or hyperplasia, history of ovarian tumor, intrauterine contraception device location, and unexplained weight loss.

3.2. Pain Descriptors and Endometriosis Relationship

There was a broad range of reported SF-MPQ total pain scores, ranging from 0 to 15, which are shown in detail in Table 2. The independent t-test results showed that the patients with an endometriosis history had statistically significantly higher pain scores overall (7.2 ± 0.59) compared to the patients with no history of endometriosis (0.34 ± 0.12), t (40) = 8.8673, p = 0.000. Furthermore, the results showed that the patients with an endometriosis history had statistically significantly higher pain scores specific to the USLs (8.15 ± 0.54) compared to the patients with no history of endometriosis (0.21 ± 0.21), t (82) = 9.1645. Patients with USL nodules demonstrated a further increase in pain scores (12.8 ± 0.38) compared to the patients with USLs with DE features but no identified nodule (7.4 ± 0.92), t (28) = 4.3366.

Table 2. Mean differences in pain scores and relationship of TVS and SST pain scores of patients with and without endometriosis.

Regions Where SST Was Tested During TVS	Frequency of Pain Observed			Short-Form McGill Pain Score. Mean ± SD (Range)			Correlation of Pain Scale for DE Versus No DE	
	All (*n* = 42)	with DE (*n* = 30)	No DE (*n* = 12)	All (*n* = 42)	with DE (*n* = 30)	No DE (*n* = 12)	t-Statistic (df)	*p*-Value
USL	29	28	1	5.9 ± 0.55 (0–14)	8.15 ± 0.54 (0–14)	0.21 ± 0.21 (0–5)	9.16 * (82)	0.0000
USL nodule (*n* = 11)	11	11	0	-	No Nodule (*n* = 19) 7.4 ± 0.92 (0–14) USL Nodule (*n* = 11) 12.8 ± 0.38 (10–14)	-	4.34 * (28)	0.0002
Ovary	33	30	3	6.4 ± 0.53 (0–15)	8.7 ± 0.47 (0–15)	0.63 ± 0.29 (0–8)	10.30 * (82)	0.0000
Post Fornix	31	29	2	6.5 ± 0.76 (0–13)	8.7 ± 0.70 (0–13)	1.1 ± 0.75 (0–8)	6.25 * (40)	0.0000
POD	21	21	0	4.3 ± 0.76 (0–13)	6.0 ± 0.89 (0–13)	0, 0 (0)	4.24 * (40)	0.0001
Bladder	8	8	0	1.2 ± 0.42 (0–10)	1.6 ± 0.57 (0–10)	0, 0 (0)	1.72 (40)	0.0926
Bowel nodule (*n* = 16)	16	16	0	-	No Nodule (*n* = 14) 0, 0 (0) Bowel Nodule (*n* = 16) 13.7 ± 0.28 (10–15)	-	44.89 * (28)	0.0000
All Areas	34	30	4	5.2 ± 0.59 (0–10.5)	7.2 ± 0.49 (1.8–11)	0.34 ± 0.19, (0–2)	8.87 * (40)	0.0000

KEY: (TVS) transvaginal ultrasound, (SST) site-specific tenderness, (SD) Standard Deviation, (*n*) sample size, (DE) Deep Endometriosis, (USL) uterosacral ligament, (POD) Pouch of Douglas, (*) statistically significant.

Spearman's correlation was used to assess the relationship between TVS endometriosis characteristics and pain scale in 42 participants. For the analysis of USL nodules, 30 participants with diagnosed endometriosis were included to compare pain levels between those with and without a focal USL nodule.

Results showed (Table 3) a strong correlation with pain scale score: $r = 0.74$ for clinical symptoms (chronic pelvic pain, dysmenorrhea, and dyspareunia); $r = 0.78$ for a positive or negative endometriosis diagnosis; $r = 0.74$ for USL thickness vs. pain score; and $r = 0.70$ when USL nodules were identified, all $p < 0.0005$. The graphs seen in Figure 2 visually demonstrate the correlations described.

Table 3. Correlation of endometriosis characteristics vs. pain scale score.

Characteristic	(*n*)	Spearman's Correlation (*r*)	*p*-Value	Interpretation
Endometriosis diagnosis vs. Overall pain scale score	42	0.78 *	0.0000	Strong Correlation
Patient pain symptoms vs. USL pain scale score	42	0.74 *	0.0000	Strong Correlation
USL thickness vs. USL pain scale score	42	0.74 *	0.0000	Strong Correlation
USL nodule vs. USL pain score	30	0.70 *	0.0001	Strong Correlation

KEY: (*r*) Spearman's correlation, (*n*) sample size, (USL) uterosacral ligament, (*) statistically significant.

3.3. Pain Descriptors for TVS Diagnosis Relationship

The paired *t*-tests showed that overall, the observers demonstrated a higher ability to correctly identify endometriosis with the pain scale information (33 ± 8.83) as opposed to not having the pain scale information (29.67 ± 6.31); a statistically significant change of 3.33 (95% CI, −6.42 to −0.24), t (5) = 2.7735, $p = 0.0392$. Table 4 shows the data spread of their diagnoses and changes, with Figure 3 graphing the results.

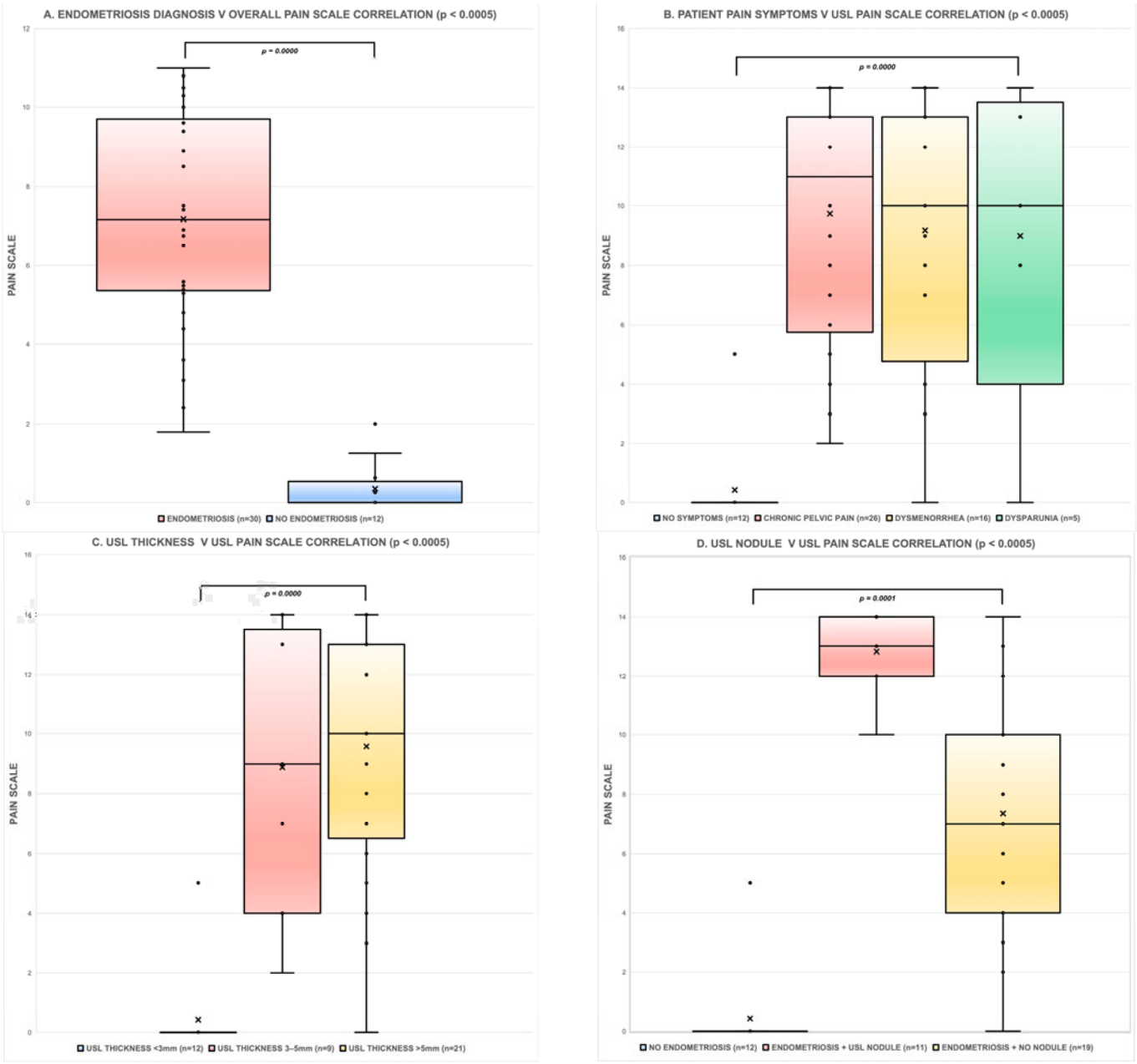


Figure 2. Whisker plots demonstrating the Spearman's correlation coefficient results for endometriosis characteristics versus pain scale. These graphs show the spread of endometriosis characteristics with patient SST pain scores on TVS (where X = mean score) with statistical significance (where all $p < 0.0005$), as represented in Table 3. (**A**) Correlation of endometriosis diagnosis (surgically or clinically by referring gynecologist) and pain; (**B**) correlation of patient clinical symptoms (chronic pelvic pain, dysmenorrhea, and dyspareunia) and pain; (**C**) correlation of USL thickness and pain; and (**D**) correlation of USL nodules (endometriosis identified including a focal USL nodule and endometriosis identified with no USL nodule seen) and pain.

Table 4. Relationship scores between diagnosis by professional observers as a collective group and individually, based before and after using pain scale across the six observers.

Variables	Before Pain Score Information Mean (DF)	After Pain Score Information Mean (DF)	Score Difference Mean (95% CI)	t-Statistic (df)	*p*-Value
All Observers					
All Patients (*n* = 42)	29.67 (6.31)	33.00 (8.83)	3.33 (−6.42, −0.24)	2.77 * (5)	0.0392
Patients With DE (*n* = 30)	19.33 (6.06)	21.50 (7.34)	2.17 (−4.86, 0.52)	2.071 (5)	0.0931
Patients With No DE (*n* = 12)	10.33 (1.63)	11.17 (1.33)	2.17 (−2.51, 0.85)	1.27 (5)	0.2586
Individual Observers					
Observer A	15.3	15.3	0	-	-
Observer B	21.3	26	4.7	2.00 (2)	0.1835
Observer C	23.3	27.3	4	3.46 (2)	0.0742
Observer D	18	20	2	3.46 (2)	0.0742
Observer E	15 3	15.3	0	-	-
Observer F	25.3	27.3	2	1.7321 (2)	0.2254

KEY: (CI) confidence interval, (*n*) sample size, (DF) degrees of freedom, (DE) Deep Endometriosis, (*) statistically significant.

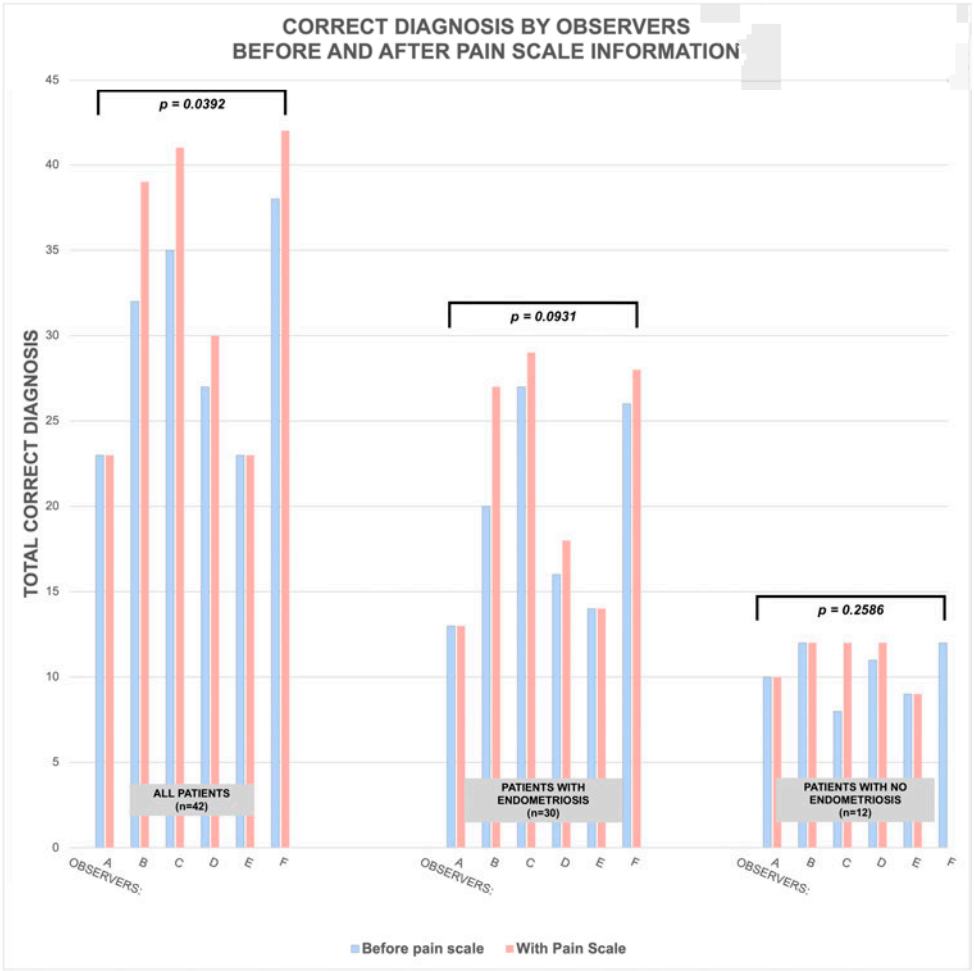


Figure 3. Graph representation of relationship of diagnostic scores of professional observers before and after using pain scale across the six observers, as shown in Table 4.

4. Discussion

This study aimed to explore the relationship between the identification of DE on TVS and pain scores on examination and its ability to assist a correct diagnosis. The mean age of the patients was 33.6 years, with all the cases of known endometriosis reporting site-specific pain on the TVS. One of the characteristics of DE is its strong association with pain [2,17], resulting in a reduction in the quality of life of its sufferers. The physical and emotional well-being of many female-born people of reproductive age is significantly affected by endometriosis pain [25,29].

While there is some academic debate regarding the association of pain symptoms and endometriosis, it is acknowledged that endometriosis has a high pain association [29]. Confliction occurs because sometimes very advanced endometriosis may not cause any symptoms [3], while in contrast, small deposits can cause severe pain [3]. However, for those individuals who have severe pain symptoms, the prevalence of DE is high [3], with this study further demonstrating that the patients with known endometriosis had significantly higher overall SF-MPQ total pain scores (7.2 ± 0.49) compared to the patients with no history of endometriosis (0.34 ± 0.19) and that there was a strong positive correlation ($r = 0.78$).

Many studies have reported that there are associations between dysmenorrhea and the size, depth, and disease stages of DE [18–20]. Severe dysmenorrhea does not definitely correlate with any DE location, but it does correlate with adhesions in the Pouch of Douglas [20,22,44]. Since USLs sit in this posterior compartment with their distal section attaching to the posterior cervix at the TU [8,14,28], there is an anatomical association of DE deposits at this rectocervical location, including the USLs, POD, bowel, rectum, and adhesions to the ovary in the presence of an endometrioma at the TU, all contributing to pelvic pain [6]. This study showed that the patients with an endometriosis history had significantly higher pain scores specific to USLs (8.15 ± 0.54) compared to the patients with no history of endometriosis (0.21 ± 0.21) and that there was a strong positive correlation ($r = 0.74$) with the USL pain score when correlated with the patients' clinical symptoms of chronic pelvic pain, dysmenorrhea, and dyspareunia.

Deep dyspareunia is also correlated with endometriotic deposits of the USLs [20,44], due to the fact that USLs contain a considerable amount of nerve tissue and that neural invasion by endometriotic lesions is correlated with the severity of pain [2,25]. During intercourse, tension on the diseased USL may trigger pain [25,44] causing those individuals to have more severe sexual dysfunction [25], with the pressure, traction, or stretching of the DE nodules exacerbating the pain symptoms. During a TVS examination, this can be replicated with direct sonopalpation, allowing SST-TVS to be quite advantageous in simultaneously visualizing any DE deposits while exacerbating patient pain symptoms, hence patient-guided replication of symptoms.

Clinically, during TVS, USLs would not be examined in isolation. However, USL examination in a routine pelvic scan is a useful starting point on its own diagnostic merit [9,12,14] to prompt further extension of the pelvic scan to look for other markers of endometriosis in the surrounding structures when a woman presents with pelvic pain [45]. Figure 4A illustrates the extensive nature of endometriosis demonstrating the association of the medialization of both ovaries with endometriomas adherent to the USLs as well as an endometriotic nodule at the TU. SST at this location was described as "sharp" with a total 13/15 pain score.

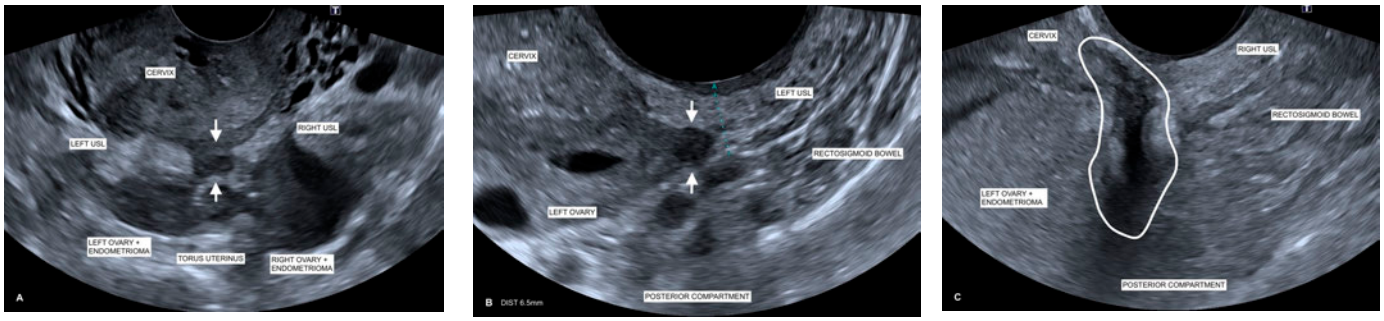


Figure 4. Ultrasound images correlating patient TVS and SST. (**A**) Endometriomas/medialized ovaries to USLs: Transverse TVS image shows there are bilateral endometriomas and medialization of both ovaries adherent to the USLs (right and left as labeled) at the torus uterinus. A focal endometriotic nodule (arrows) can be seen between the right and left USLs. This patient has confirmed endometriosis associated with long-standing pelvic pain. Correlating SST at this location was described as "sharp" with a total 13/15 pain score. (**B**) Thickened USL and nodule: USL DE in a woman with severe pelvic pain and dyspareunia who was confirmed to have extensive endometriosis in laparoscopy. Sagittal TVS image shows an irregular and thickened left USL (labeled with caliper measuring 6.5 mm) with adherence of the left ovary (labeled). There is an associated focal endometriotic nodule (arrows) adherent to the adjacent structures. Calipers demonstrate a 6.5 mm thickness of the left USL measured at the thickest point. Correlating SST at this location was described as "sharp" with a total 12/15 pain score. (**C**) Rectosigmoid DE adherent to USL: Sagittal TVS image demonstrating extensive deep infiltrative endometriosis. Endometriosis plaque deposits (circled) can be seen at the level of the rectosigmoid bowel, tethered to the inferior margin of the left ovary (labeled). The left ovary is medialized, with an endometrioma adherent to the torus uterinus, extending to the right USL. Correlating SST at this location was described as "sharp" with a total 10/15 pain score.

It has been previously established that the presence of a rectovaginal endometriotic nodule is always associated with pelvic pain, dysmenorrhea, and/or deep dyspareunia [2,5,21,22]. This study supported these findings, with patients reporting a particularly high degree of SST pain scores (12.8 $\pm$ 0.38), with a range of 10–14 in the patients with focal DE nodules of the USL. Findings also showed that there was a strong positive correlation with the pain score where USL nodules were identified (r = 0.70), as well as with USL thickness (r = 0.74), since USL thickness can be an indicator of DE disease [12]. Figure 4B illustrates these findings, showing an irregular and thickened left USL with adherence of the left ovary associated with a focal endometriotic nodule, with the correlating SST at this location described as "sharp" with a total 12/15 pain score. An explanation for this is that the growth of nerve fibers in endometriotic deposits is considered a mechanism of severe pain in endometriosis [17,18,46] and that there is a close histological relationship between some deep retroperitoneal endometriotic lesions and the subperitoneal nerves and that this relationship is correlated with pain [17]. It has also been demonstrated that in rectovaginal septum endometriotic nodules, a high proportion of the nerves is encapsulated in the nodular fibrosis of the deposit [2]. Endometriotic lesions are also found in close histological relationship with the nerves of the colon, even at a distance from the palpated area, and seem to infiltrate the large bowel with tenderness around the nerves [17]. In essence, a characteristic of DE nodules is that they are "pain triggers" [44]. Figure 4C visualizes this with rectosigmoid bowel DE adherent to the inferior margin of the ovarian endometrioma, extending to the right USL. Correlating SST at this location was described as "sharp" with a total 10/15 pain score.

There is clear evidence that the IDEA [8] guidelines have improved reproducible TVS diagnosis of DE in both specialist and general settings [9]. The IDEA guidelines [8] also involve checking for 'soft markers' such as site-specific tenderness, including over the USLs. Further studies have reported that SST on probe pressure can assist nodule identification [47]. When attention is given to site tenderness during examination, a high

specificity of 94% is achieved in the detection of DE [36], with the results of this study further suggesting tenderness-directed scanning as a useful component of the ultrasound technique [12,31]. This hybrid approach of anatomical changes and pain identification follows clinical advice from Chapron et al., where "detecting a nodule during the vaginal examination by attention to subtle signs such as asymmetric uterosacral ligaments appearing irregular, hardened, and taut with the essential sign is that firm palpation of these lesions gives rise to pain identical to that of the deep dyspareunia that the patient describes" [24]. In this study, when the professional observers were given the extra SST-TVS information for each patient, there was a higher ability to correctly identify endometriosis with the pain scale information (33 $\pm$ 8.83), as opposed to not having the pain scale information (29.67 $\pm$ 6.31); a statistically significant change of 3.33 (95% CI, -6.42 to -0.24), hence indicating that a pain scale can potentially be used to improve diagnosis of endometriosis. However, there were some limitations with our results when dividing the 42 participants into those with DE and those without. While the results further demonstrated a higher ability to diagnose DE, the results were not statistically significant, with the pain scale data showing some promise, although they did not show any significant difference. An explanation for this is that the pelvic scan itself was very thorough, and the observers were familiar with the protocols and the criteria for diagnosis on the basis of pelvic scans alone.

Although a detailed pelvic scan can diagnose endometriosis, SST and pain scoring can help prompt further investigation in general settings where people are not trained to perform endo scans, which would be a practical application.

Regardless, the findings are encouraging in that there is a benefit in incorporating the patient's pain response when considering a DE diagnosis, broadening ultrasound imaging interpretation to consider clinical elements, as all areas should be examined with consideration to each other when performing TVS for DE. This includes listening to the patient to consider SST to guide how to extend the scan to investigate for DE thoroughly.

5. Strengths and Limitations

There are some limitations to this study that need acknowledgment. Firstly, the observers did not perform the scan in real time as this was not feasible. Also, given the nature of the pain scale, the responses were based on a self-report, and since the perception of pain is widely variable and subjective, it was not possible to confirm. Secondly, in some cases, USL DE may have been associated with other endometriotic lesions (i.e., vagina or anterior rectal wall), which have been correlated with the presence of dyspareunia. However, this study was not designed to correlate the presence of dyspareunia with the anatomical location of endometriotic lesions. Thirdly, the results apply only to patients who had pain symptoms and therefore do not include the population of people with endometriosis who are non-symptomatic or those with endometriosis-associated pain who are managed without imaging or without seeking medical assistance. Furthermore, our study outcomes were limited to the sample size, which may not accurately represent the target population and may limit generalizability. The published Australian National Women's Health Survey [48] reports the prevalence of chronic pelvic pain in the general population to be approximately 25–30%.

Future studies ideally need larger numbers to obtain a true representation of pain in the population. And fourthly, our study population is limited to reflect a private general imaging setting in Australia; thus, future studies with more representation are needed.

Despite these limitations, our study has several strengths, including its novelty in assessing the ultrasound relationship between site-specific tenderness and pain-related symptoms for endometriosis and the uterosacral ligaments. Other strengths include the prospective approach, blinding examiners to each other's findings, a multidisciplinary approach, and that all assessments were performed at a single center and the images were collected by one sonographer using real-time ultrasound examinations. The reliability of our study is further strengthened by the scans conducted using a rigorous best-practice

protocol. The present study provides a foundation for future research to explore the role of SST in the ultrasound diagnosis of endometriosis.

6. Conclusions

Individuals experiencing pelvic pain associated with endometriosis routinely have their pain discounted. This leads to considerable delays in diagnosis, resulting in years of physical suffering and associated health anxiety. This study demonstrated that patients with an endometriosis history have significantly higher pain scores on TVS compared to patients with no history of endometriosis. There was also a strong positive correlation with pain score when correlated with clinical symptoms (chronic pelvic pain, dysmenorrhea, and dyspareunia), USL thickness, and where USL nodules were identified. The findings indicate that there is value in this approach, with patient SST-TVS pain scores having a strong correlation to the ultrasound image criteria and hence, medical practitioners should be paying attention to pain symptoms experienced by patients. Listening to patients' symptoms and incorporating these into the diagnosis of TVS could help earlier endometriosis diagnosis as well as overcome situations where patients feel that their concerns are dismissed. Inclusion of SST into TVS shows promise in the diagnosis of endometriosis. However, this finding needs to be interpreted with caution, as it was not statistically significant. Education about TVS for endometriosis, including understanding incorporating SST as a pain scale, can be of benefit, especially in clinics where endometriosis diagnostic skills are limited.

Author Contributions: Conceptualization, S.M., N.P., E.B. and K.J.C.; methodology, S.M., N.P., E.B. and K.J.C.; validation, S.M., N.P. and E.B.; formal analysis, S.M., N.P. and E.B.; investigation, S.M.; resources, S.M.; data curation, S.M.; writing—original draft preparation, S.M.; writing—review and editing, S.M., N.P. and E.B.; supervision, S.M., N.P., E.B. and K.J.C.; project administration, S.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the University of South Australia Human Research Ethics Committee (project number 204278 on 4 November 2021) for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to patient confidentiality restrictions.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Zondervan, K.T.; Becker, C.M.; Missmer, S.A. Endometriosis. *N. Engl. J. Med.* **2020**, *382*, 1244–1256. [CrossRef] [PubMed]
2. Anaf, V.; Simon, P.; El Nakadi, I.; Fayt, I.; Buxant, F.; Simonart, T.; Peny, M.-O.; Noel, J.-C. Relationship between endometriotic foci and nerves in rectovaginal endometriotic nodules. *Hum. Reprod.* **2000**, *15*, 1744–1750. [CrossRef] [PubMed]
3. Smolarz, B.; Szyłło, K.; Romanowicz, H. Endometriosis: Epidemiology, Classification, Pathogenesis, Treatment and Genetics (Review of Literature). *Int. J. Mol. Sci.* **2021**, *22*, 10554. [CrossRef] [PubMed]
4. Zhou, Y.; Su, Y.; Liu, H.; Wu, H.; Xu, J.; Dong, F. Accuracy of transvaginal ultrasound for diagnosis of deep infiltrating endometriosis in the uterosacral ligaments: Systematic review and meta-analysis. *J. Gynecol. Obstet. Hum. Reprod.* **2021**, *50*, 101953. [CrossRef] [PubMed]
5. Koninckx, P.R.; Meuleman, C.; Demeyere, S.; Lesaffre, E.; Cornillie, F.J. Suggestive evidence that pelvic endometriosis is a progressive disease, whereas deeply infiltrating endometriosis is associated with pelvic pain. *Fertil. Steril.* **1991**, *55*, 759–765. [CrossRef]
6. Scioscia, M.; Scardapane, A.; Virgilio, B.A.; Libera, M.; Lorusso, F.; Noventa, M. Ultrasound of the uterosacral ligament, parametrium, and paracervix: Disagreement in terminology between imaging anatomy and modern gynecologic surgery. *J. Clin. Med.* **2021**, *10*, 437. [CrossRef]
7. Becker, C.M.; Bokor, A.; Heikinheimo, O.; Horne, A.; Jansen, F.; Kiesel, L.; King, K.; Kvaskoff, M.; Nap, A.; Petersen, K.; et al. ESHRE guideline: Endometriosis. *Hum. Reprod. Open* **2022**, *2022*, hoac009. [CrossRef]

8. Guerriero, S.; Condous, G.; van den Bosch, T.; Valentin, L.; Leone, F.P.G.; Van Schoubroeck, D.; Exacoustos, C.; Installé, A.J.F.; Martins, W.P.; Abrao, M.S.; et al. Systematic approach to sonographic evaluation of the pelvis in women with suspected endometriosis, including terms, definitions and measurements: A consensus opinion from the International Deep Endometriosis Analysis (IDEA) group. *Ultrasound Obstet. Gynecol.* **2016**, *48*, 318–332. [CrossRef]
9. Freger, S.M.; Turnbull, V.; McGowan, K.; Leonardi, M. Prospective diagnostic test accuracy of transvaginal ultrasound posterior approach for uterosacral ligament and torus uterinus deep endometriosis. *Ultrasound Obstet. Gynecol.* **2024**, *63*, 263–270. [CrossRef]
10. Condous, G.; Gerges, B.; Thomassin-Naggara, I.; Becker, C.; Tomassetti, C.; Krentel, H.; van Herendael, B.J.; Malzoni, M.; Abrao, M.S.; Saridogan, E.; et al. Non-invasive imaging techniques for diagnosis of pelvic deep endometriosis and endometriosis classification systems: An International Consensus Statement. *Ultrasound Obstet. Gynecol.* **2024**, *64*, 129–144. [CrossRef]
11. Guerriero, S.; Ajossa, S.; Minguez, J.A.; Jurado, M.; Mais, V.; Melis, G.B.; Alcazar, J.L. Accuracy of transvaginal ultrasound for diagnosis of deep endometriosis in uterosacral ligaments, rectovaginal septum, vagina and bladder: Systematic review and meta-analysis. *Ultrasound Obstet. Gynecol.* **2015**, *46*, 534–545. [CrossRef] [PubMed]
12. Maple, S.; Chalmers, K.J.; Bezak, E.; Henry, K.; Parange, N. Ultrasound Characteristics and Scanning Techniques of Uterosacral Ligaments for the Diagnosis of Endometriosis. *J. Ultrasound Med.* **2022**, *42*, 1193–1209. [CrossRef] [PubMed]
13. Gerges, B.; Li, W.; Leonardi, M.; Mol, B.W.; Condous, G. Meta-analysis and systematic review to determine the optimal imaging modality for the detection of uterosacral ligaments/torus uterinus, rectovaginal septum and vaginal deep endometriosis. *Hum. Reprod. Open* **2021**, *2021*, hoab041. [CrossRef] [PubMed] [PubMed Central]
14. Leonardi, M.; Condous, G. A pictorial guide to the ultrasound identification and assessment of uterosacral ligaments in women with potential endometriosis. *Australas. J. Ultrasound Med.* **2019**, *22*, 157–164. [CrossRef]
15. Young, S.W.; Jha, P.; Chamié, L.; Rodgers, S.; Kho, R.M.; Horrow, M.M.; Glanc, P.; Feldman, M.; Groszmann, Y.; Khan, Z.; et al. Society of Radiologists in Ultrasound Consensus on Routine Pelvic US for Endometriosis. *Radiology* **2024**, *311*, e232191. [CrossRef]
16. Deslandes, A. and Leonardi, M. Proposed simplified protocol for initial assessment of endometriosis with transvaginal ultrasound. *Ultrasound Obstet. Gynecol.* **2024**. [CrossRef]
17. Anaf, V.; El Nakadi, I.; Simon, P.; Van de Stadt, J.; Fayt, I.; Simonart, T.; Noel, J. Preferential infiltration of large bowel endometriosis along the nerves of the colon. *Hum. Reprod.* **2004**, *19*, 996–1002. [CrossRef] [PubMed]
18. Vercellini, P.; Fedele, L.; Aimi, G.; Pietropaolo, G.; Consonni, D.; Crosignani, P. Association between endometriosis stage, lesion type, patient characteristics and severity of pelvic pain symptoms: A multivariate analysis of over 1000 patients. *Hum. Reprod.* **2006**, *22*, 266–271. [CrossRef]
19. Fedele, L.; Bianchi, S.; Bocciolone, L.; Di Nola, G.; Parazzini, F. Pain symptoms associated with endometriosis. *Obstet. Gynecol.* **1992**, *79 Pt 1*, 767–769.
20. Chapron, C.; Fauconnier, A.; Dubuisson, J.; Barakat, H.; Vieira, M.; Bréart, G. Deep infiltrating endometriosis: Relation between severity of dysmenorrhoea and extent of disease. *Hum. Reprod.* **2003**, *18*, 760–766. [CrossRef]
21. Koninckx, P.R.; Martin, D.C. Deep endometriosis: A consequence of infiltration or retraction or possibly adenomyosis externa? *Fertil Steril.* **1992**, *58*, 924–928. [CrossRef] [PubMed]
22. Porpora, M.; Koninckx, P.; Piazze, J.; Natili, M.; Colagrande, S.; Cosmi, E. Correlation between endometriosis and pelvic pain. *J. Am. Assoc. Gynecol. Laparosc.* **1999**, *6*, 429–434. [CrossRef] [PubMed]
23. Chapron, C.; Fauconnier, A.; Vieira, M.; Barakat, H.; Dousset, B.; Pansini, V.; Vacher-Lavenu, M.C.; Dubuisson, J.B. Anatomical distribution of deeply infiltrating endometriosis: Surgical implications and proposition for a classification. *Hum. Reprod.* **2003**, *18*, 157–161. [CrossRef]
24. Chapron, C.; Dubuisson, J.B. Management of deep endometriosis. *Ann. N. Y. Acad. Sci.* **2001**, *943*, 276–280. [CrossRef] [PubMed]
25. Ferrero, S.; Esposito, F.; Abbamonte, L.H.; Anserini, P.; Remorgida, V.; Ragni, N. Quality of sex life in women with endometriosis and deep dyspareunia. *Fertil. Steril.* **2005**, *83*, 573–579. [CrossRef]
26. Kor, E.; Mostafavi, S.R.S.; Mazhin, Z.A.; Dadkhah, A.; Kor, A.; Arvanagh, S.H.; Noroozi, S.G.; Sadri, G. Relationship between the severity of endometriosis symptoms (dyspareunia, dysmenorrhea and chronic pelvic pain) and the spread of the disease on ultrasound. *BMC Res. Notes* **2020**, *13*, 546. [CrossRef]
27. Bazot, M.; Lafont, C.; Rouzier, R.; Roseau, G.; Thomassin-Naggara, I.; Daraï, E. Diagnostic accuracy of physical examination, transvaginal sonography, rectal endoscopic sonography, and magnetic resonance imaging to diagnose deep infiltrating endometriosis. *Fertil. Steril.* **2009**, *92*, 1825–1833. [CrossRef]
28. Vu, D.; Haylen, B.T.; Tse, K.; Farnsworth, A. Surgical anatomy of the uterosacral ligament. *Int. Urogynecol. J.* **2010**, *21*, 1123–1128. [CrossRef]
29. Morotti, M.; Vincent, K.; Becker, C.M. Mechanisms of pain in endometriosis. *Eur. J. Obstet. Gynecol. Reprod. Biol.* **2017**, *209*, 8–13. [CrossRef]
30. Montanari, E.; Dauser, B.; Keckstein, J.; Kirchner, E.; Nemeth, Z.; Hudelist, G. Association between disease extent and pain symptoms in patients with deep infiltrating endometriosis. *Reprod. Biomed. Online* **2019**, *39*, 845–851. [CrossRef]
31. Young, S.W.; Dahiya, N.; Patel, M.D.; Abrao, M.S.; Magrina, J.F.; Temkit, M.; Kho, R.M. Initial Accuracy of and Learning Curve for Transvaginal Ultrasound with Bowel Preparation for Deep Endometriosis in a US Tertiary Care Center. *J. Minim. Invasive Gynecol.* **2017**, *24*, 1170–1176. [CrossRef] [PubMed]
32. Melzack, R. The short-form McGill pain questionnaire. *Pain* **1987**, *30*, 191–197. [CrossRef] [PubMed]

33. Reid, S.; Leonardi, M.; Lu, C.; Condous, G. The association between ultrasound-based 'soft markers' and endometriosis type/location: A prospective observational study. *Eur. J. Obstet. Gynecol. Reprod. Biol.* **2019**, *234*, 171–178. [CrossRef] [PubMed]
34. Saba, L.; Guerriero, S.; Sulcis, R.; Pilloni, M.; Ajossa, S.; Melis, G.; Mallarini, G. MRI and "tenderness guided" transvaginal ultrasonography in the diagnosis of recto-sigmoid endometriosis. *J. Magn. Reson. Imaging* **2012**, *35*, 352–360. [CrossRef]
35. Guerriero, S.; Ajossa, S.; Gerada, M.; D'Aquila, M.; Piras, B.; Melis, G.B. "Tenderness-guided" transvaginal ultrasonography: A new method for the detection of deep endometriosis in patients with chronic pelvic pain. *Fertil. Steril.* **2007**, *88*, 1293–1297. [CrossRef] [PubMed]
36. Guerriero, S.; Ajossa, S.; Gerada, M.; Virgilio, B.; Angioni, S.; Melis, G.B. Diagnostic value of transvaginal 'tenderness-guided' ultrasonography for the prediction of location of deep endometriosis. *Hum. Reprod.* **2008**, *23*, 2452–2457. [CrossRef] [PubMed]
37. Cuschieri, S. The STROBE guidelines. *Saudi J. Anaesth.* **2019**, *13* (Suppl. 1), S31–S34. [CrossRef]
38. Faul, F. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* **2007**, *39*, 175–191. [CrossRef]
39. ASUM. Australian Society of Ultrasound in Medicine—Guidelines on the Performance of a Gynaecological Ultrasound Examination. Available online: https://www.asum.com.au/files/public/SoP/curver/Obs-Gynae/Gynaecological-GL-2020.pdf (accessed on 3 May 2024).
40. Leonardi, M.; Condous, G. How to perform an ultrasound to diagnose endometriosis. *Australas J. Ultrasound. Med.* **2018**, *21*, 61–69. [CrossRef]
41. Bourdel, N.; Alves, J.; Pickering, G.; Ramilo, I.; Roman, H.; Canis, M. Systematic review of endometriosis pain assessment: How to choose a scale? *Hum. Reprod. Update* **2015**, *21*, 136–152. [CrossRef]
42. Fabbri, E.; Villa, G.; Mabrouk, M.; Guerrini, M.; Montanari, G.; Paradisi, R.; Venturoli, S.; Seracchioli, R. McGill Pain Questionnaire: A multi-dimensional verbal scale assessing postoperative changes in pain symptoms associated with severe endometriosis. *J. Obstet. Gynaecol. Res.* **2009**, *35*, 753–760. [CrossRef] [PubMed]
43. StataCorp. *Stata Statistical Software, Release 18*; StataCorp LLC: College Station, TX, USA, 2023.
44. Fauconnier, A.; Chapron, C.; Dubuisson, J.-B.; Vieira, M.; Dousset, B.; Bréart, G. Relation between pain symptoms and the anatomic location of deep infiltrating endometriosis. *Fertil. Steril.* **2002**, *78*, 719–726. [CrossRef] [PubMed]
45. Young, S.W.; Groszmann, Y.; Dahiya, N.; Caserta, M.; Yi, J.; Wasson, M.; Patel, M.D. Sonographer-acquired ultrasound protocol for deep endometriosis. *Abdom. Radiol.* **2020**, *45*, 1659–1669. [CrossRef] [PubMed]
46. Remorgida, V.; Ragni, N.; Ferrero, S.; Anserini, P.; Torelli, P.; Fulcheri, E. The involvement of the interstitial Cajal cells and the enteric nervous system in bowel endometriosis. *Hum. Reprod.* **2005**, *20*, 264–271. [CrossRef]
47. El-Maadawy, S.M.; Alaaeldin, N.; Nagy, C.B. Role of preoperative ultrasound mapping in the surgical management of deep infiltrating endometriosis: A prospective observational study. *Egypt. J. Radiol. Nucl. Med.* **2021**, *52*, 1–11. [CrossRef]
48. Jean Hailes 2023 National Women's Health Survery. Pelvic Pain in Australian Women 2023. Available online: https://www.jeanhailes.org.au/research/womens-health-survey/pelvic-pain-in-australian-women (accessed on 3 July 2024).

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

4.3 Discussion and Conclusion

4.3.1 Key Findings

This study found that patients with a history of endometriosis reported significantly higher pain scores during TVS compared to those without such a history. Incorporating SST into TVS evaluations demonstrated potential for improving the accuracy of endometriosis diagnoses, particularly when pain scale data was included.

Incorporating SST and pain scale education into TVS protocols for endometriosis could therefore be beneficial, especially in clinics with limited diagnostic expertise. Enhancing sonographers' understanding of endometriosis and pain mechanisms may contribute to more accurate and comprehensive assessments.

4.3.2 Novel Contribution to Literature

A key novel contribution of this research is its exploration of the correlation between SST and TVS findings in diagnosing endometriosis, particularly in the USLs. The study indicates that combining SST with TVS enhances diagnostic accuracy, showing strong correlations with clinical symptoms, USL thickness, and USL nodules. Furthermore, the findings suggest that pain scores influence diagnostic decisions, supporting the integration of SST with TVS to improve detection rates.

These results highlight the value of incorporating patient pain responses into TVS evaluations. While detailed pelvic scans are essential for diagnosing endometriosis, SST pain descriptors can prompt further investigation. Educating clinicians on integrating SST into TVS assessments could be especially advantageous in settings with limited expertise in diagnosing endometriosis.

4.3.3 Strengths and Limitations

This study's strengths include:

1. Rigid methodology that followed The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines[81].
2. Its novel assessment of the ultrasound relationship between SST and pain symptoms in endometriosis, a prospective design, blinding of examiners, a multidisciplinary approach, and single-centre data collection by one sonographer.

3. The use of best practice protocols further ensures reliability, providing a foundation for future research on SST's role in ultrasound diagnosis of endometriosis.

Several limitations must be considered:

1. The study sample included only patients with pain symptoms, excluding those with asymptomatic endometriosis or those managed without imaging or medical assistance. This limits the generalisability of the findings.
2. The small sample size may not accurately represent the broader population. The Australian National Women's Health Survey (2022) estimates that 25–30% of the general population experiences chronic pelvic pain[82]. Future studies should include larger cohorts to better represent the prevalence and characteristics of pain in the population.
3. The lack of real-time scanning by observers, which was not feasible in this study. Pain scale responses were also self-reported, making them subjective and difficult to standardise due to the wide variability in individual pain perception. These factors should be addressed in future research to strengthen the reliability and applicability of findings.

Chapter 5

Summary and Conclusion

This thesis investigated the use of ultrasound for diagnosing endometriosis by examining the characteristics of normal and abnormal uterosacral ligaments, including site-specific tenderness and intra and interobserver reliability between experienced and less experienced examiners in general ultrasound practices.

5.1 Summary of Main Findings of Thesis

Chapter 2 of this thesis presented a systematic review of the literature that addressed the first aim of this research thesis. The review identified consistent ultrasound techniques for USL evaluation and the distinction between normal and abnormal USL appearances. Despite agreement on methods, descriptors and measurement criteria lacked standardisation or validation. Normal USLs were described as smooth, linear, hyperechoic, homogeneous structures that slide freely with transducer pressure, while abnormal USLs were thickened and heterogenous, often with hypoechoic linear thickening and irregular margins. The agreement on descriptors was inconsistent. Findings from the literature highlighted that most studies were conducted in specialist centres with highly trained sonologists or radiologists, raising questions about the reproducibility of these techniques in general settings.

To address this gap, **Chapter 3** presented an intra and interobserver reliability study involving 42 patients (30 with confirmed endometriosis and 12 controls) and six observers with varying experience levels (2–16 years). Findings indicated that both experienced and less experienced operators could reliably assess USLs using TVS. However, variability arose in determining where to measure USL thickness and identifying abnormal characteristics, particularly in cases of DE. This study confirmed the feasibility of incorporating TVS into general practice but highlighted the need to refine and validate diagnostic techniques.

Another gap identified in the systematic review was the correlation of site-specific tenderness with ultrasound findings. To resolve this question, **Chapter 4** evaluated the role of SST and the addition of patient pain scores in diagnosing USL DE. Findings suggest SST and pain scoring are valuable for identifying endometriosis, especially in general settings with limited specialised imaging expertise in DE.

5.2 Thesis Overall Contribution to the Literature

This project provides an evaluation of TVS for diagnosing endometriosis, with a particular focus on USL assessment in non-specialist settings.

1. **Systematic Review - Chapter 2:** Identified gaps in reporting and standardisation, emphasising the need for validated protocols and targeted training to improve diagnostic reliability in general clinical settings.
2. **Interrater Study - Chapter 3:** Demonstrated the feasibility of incorporating USL examination into routine pelvic scans, showing that TVS can reliably detect thickened USLs and nodules even in non-specialist settings.
3. **Observational Study - Chapter 4:** Introduces the integration of SST with TVS, highlighting the potential of SST to improve diagnostic accuracy and align ultrasound findings with patient-reported pain.

Together, these contributions underscore the potential of standardised ultrasound protocols and SST integration to improve the early and accurate diagnosis of endometriosis, bridging the gap between specialist and general practice.

5.3 Limitations of Thesis

The project encountered several limitations:

1. **Methodological Issues**: No surgical data was obtained, and there was no correlation with MRI. This research had exclusive focus on TVS appearances of USLs without determining whether laparoscopic excision of endometriosis had been performed introduces ambiguity. It remains unclear whether the observed USLs were native or altered post-surgically, potentially affecting the results. Additionally, confirmation bias may have influenced findings, as the sonographer was not blinded to other pelvic pathologies. The reliance on offline imaging further limits the study's real-world applicability.
2. **Generalisability:** Findings are limited by small sample sizes, and the subjective nature of pain reporting. The focus on a single imaging practice restricts the relevance of findings to general clinical practice.

Despite these challenges, the project establishes a strong foundation for standardising ultrasound protocols and enhancing endometriosis diagnostics in general settings.

5.4 Future Work

This thesis was the first to investigate the transvaginal assessment of USLs for diagnosing endometriosis using the IDEA consensus guidelines in a general imaging setting. While promising, future studies should:

1. **Validate and standardise techniques, criteria, and terminology for assessing USL DE.** While good reliability was found with the techniques used, future research should aim to validate and standardise techniques, criteria, and terminology for assessing USL DE to enhance diagnostic accuracy and consistency. Validation efforts should include testing the reproducibility of the ultrasound techniques across diverse clinical settings, ensuring their applicability beyond specialised centres. This involves establishing consensus on diagnostic criteria, refining measurement techniques, and developing clear guidelines for differentiating between normal and abnormal USLs. Standardising terminology is crucial to facilitate clear

communication among clinicians and researchers and to ensure consistency in interpreting findings.

2. **Investigate reliable USL thickness cut-offs and their diagnostic relevance** Future studies are needed to identify reliable cut-offs for USL thickness to determine if there is any relevance to measuring USLs and correlate with surgical diagnosis and outcomes.
3. **Explore larger, more diverse populations to better represent the prevalence of chronic pelvic pain and refine SST-TVS findings**. Pain scale findings for SST-TVS findings are encouraging that there is benefit in incorporating patients pain response when considering a DE diagnosis broadening ultrasound imaging interpretation. The prevalence of chronic pelvic pain in the general population, is approximately 25-30%[82], and our study population is limited to reflect a private general imaging setting in Australia, thus future studies ideally need larger numbers across rural and metropolitan settings get a true representation of pain in the population.
4. **Address the training needs of sonographers and radiologists in general settings, implementing and evaluating education programs to enhance diagnostic outcomes.** Future studies are needed to address the translation of these techniques into general radiology practices Specifically, it is essential to investigate the needs of sonographers and radiologists in general settings. This includes determining whether additional training is needed for sonographers and radiologists in a general radiology setting, implementing training if there is a need and examining outcomes after implementation.
5. **Addressing the need for updated and standardised clinical protocols for scanning in general ultrasound departments.** Developing standardised protocols for general ultrasound practices will improve diagnostic accuracy, reduce delays, and enhance patient care for those with endometriosis.

5.5 Thesis Conclusion

This thesis provides an evaluation of TVS for diagnosing deep endometriosis, with a focus on assessing USLs in general imaging settings. It identifies key ultrasound techniques and characteristics of normal and abnormal USLs, such as echogenicity, thickness, and nodules, and demonstrates that both experienced and less experienced

practitioners can reliably assess USLs using TVS. The study also explores the correlation between USL thickness and DE, confirming its diagnostic relevance.

A key finding is the potential of integrating SST into TVS protocols. Women with pelvic pain related to endometriosis often face prolonged diagnostic delays, exacerbating physical suffering and health anxiety. Incorporating SST into TVS provides a patient-centred approach that validates pain symptoms and can facilitate earlier diagnosis. This is particularly valuable in non-specialist settings, where diagnostic delays are more common.

The thesis underscores the need for standardised protocols and educational resources for sonographers, focusing on reproducible TVS techniques, diagnostic criteria, and SST integration. These efforts have the potential to enhance diagnostic accuracy, particularly in clinics with limited expertise in endometriosis imaging. Establishing and validating such methods could reduce delays, improve patient experiences, and enable more consistent diagnoses across general and specialised healthcare settings.

While further research is needed to validate findings and address training needs, this thesis marks a significant step toward improving endometriosis diagnostics and patient care in non-specialist imaging practices, particularly within Australian general imaging settings.

References

References from published works in this thesis are excluded from the list.

1. Bazot M, Thomassin I, Hourani R, Cortez A, Darai E. Diagnostic accuracy of transvaginal sonography for deep pelvic endometriosis. *Ultrasound in Obstetrics and Gynecology.* 2004;24(2):180-185. http://dx.doi.org/10.1002/uog.1108.
2. Chapron C, Dubuisson JB. Management of deep endometriosis. *Ann N Y Acad Sci.* 2001;943:276-280. https://doi.org/10.1111/j.1749-6632.2001.tb03808.x.
3. RANZCOG. Australian clinical practice guideline for the diagnosis and management of endometriosis (2021). Royal Australian and New Zealand College of Obstetrics and Gynaecology, Melbourne, Australia. 2021.
4. Zondervan KT, Becker CM, Koga K, Missmer SA, Taylor RN, Viganò P. Endometriosis. *Nature Reviews Disease Primers.* 2018;4(1):9. https://doi.org/10.1038/s41572-018-0008-5.
5. Armour M, Ciccia D, Yazdani A, et al. Endometriosis research priorities in Australia. *Australian and New Zealand Journal of Obstetrics and Gynaecology.* 2023;63(4):594-598. https://doi.org/10.1111/ajo.13699.
6. Smolarz B, Szyłło K, Romanowicz H. Endometriosis: Epidemiology, Classification, Pathogenesis, Treatment and Genetics (Review of Literature). *Int J Mol Sci.* 2021;22(19). https://doi.org/10.3390/ijms221910554.
7. Becker CM, Bokor A, Heikinheimo O, et al. ESHRE guideline: endometriosis. *Human Reproduction Open.* 2022;2022(2). https://doi.org/10.1093/hropen/hoac009.
8. National Action Plan for Endometriosis: Australian Government, Department of Health. 2018. https://www.health.gov.au/sites/default/files/national-action-plan-for-endometriosis.pdf.
9. O'Hara R, Rowe H, Fisher J. Managing endometriosis: a cross-sectional survey of women in Australia. *Journal of Psychosomatic Obstetrics & Gynecology.* 2020:1-8. https://doi.org/10.1080/0167482X.2020.1825374.
10. Surrey E, Soliman AM, Trenz H, Blauer-Peterson C, Sluis A. Impact of Endometriosis Diagnostic Delays on Healthcare Resource Utilization and Costs. *Adv Ther.* 2020;37(3):1087-1099. https://doi.org/10.1007/s12325-019-01215-x.
11. Zondervan KT, Becker CM, Missmer SA. Endometriosis. *New England Journal of Medicine.* 2020;382(13):1244-1256. https://doi.org/10.1056/NEJMra1810764.

12. Klemmt PA, Carver JG, Koninckx P, McVeigh EJ, Mardon HJ. Endometrial cells from women with endometriosis have increased adhesion and proliferative capacity in response to extracellular matrix components: towards a mechanistic model for endometriosis progression. *Hum Reprod.* 2007;22(12):3139-3147. https://doi.org/10.1093/humrep/dem262.

13. ACOG. The American College of Obstetricians and Gynecologists - Practice bulletin no. 114: management of endometriosis. *Obstet Gynecol.* 2010;116(1):223-236. https://doi.org/10.1097/AOG.0b013e3181e8b073.

14. Crump J, Suker A, White L. Endometriosis: A review of recent evidence and guidelines. *Australian Journal for General Practitioners.* 01/19 2024;53:11-18.

15. Morotti M, Vincent K, Becker CM. Mechanisms of pain in endometriosis. *Eur J Obstet Gynecol Reprod Biol.* 2017;209:8-13. https://doi.org/10.1016/j.ejogrb.2016.07.497.

16. Remorgida V, Ragni N, Ferrero S, Anserini P, Torelli P, Fulcheri E. The involvement of the interstitial Cajal cells and the enteric nervous system in bowel endometriosis. *Hum Reprod.* 2005;20(1):264-271. https://doi.org/10.1093/humrep/deh568.

17. Vercellini P, Fedele L, Aimi G, Pietropaolo G, Consonni D, Crosignani PG. Association between endometriosis stage, lesion type, patient characteristics and severity of pelvic pain symptoms: a multivariate analysis of over 1000 patients. *Hum Reprod.* 2006;22(1):266-271. https://doi.org/10.1093/humrep/del339.

18. Anaf V, El Nakadi I, Simon P, et al. Preferential infiltration of large bowel endometriosis along the nerves of the colon. *Hum Reprod.* 2004;19(4):996-1002. https://doi.org/10.1093/humrep/deh150.

19. Scioscia M, Scardapane A, Virgilio BA, Libera M, Lorusso F, Noventa M. Ultrasound of the uterosacral ligament, parametrium, and paracervix: Disagreement in terminology between imaging anatomy and modern gynecologic surgery. *J.* 2021;10(3):1-11. http://dx.doi.org/10.3390/jcm10030437.

20. Johnson NP, Hummelshoj L, Adamson GD, et al. World Endometriosis Society consensus on the classification of endometriosis. *Hum Reprod.* 2017;32(2):315-324. https://doi.org/10.1093/humrep/dew293.

21. Young SW, Jha P, Chamié L, et al. Society of Radiologists in Ultrasound Consensus on Routine Pelvic US for Endometriosis. *Radiology.* 2024;311(1):e232191. https://doi.org/10.1148/radiol.232191.

22. Guerriero S, Condous G, van den Bosch T, et al. Systematic approach to sonographic evaluation of the pelvis in women with suspected endometriosis, including terms, definitions and measurements: a consensus opinion from the International Deep Endometriosis Analysis (IDEA) group. *Ultrasound Obstet Gynecol.* 2016;48(3):318-332. https://doi.org/10.1002/uog.15955.

23. Tomassetti C, Johnson NP, Petrozza J, et al. An International Terminology for Endometriosis, 2021. *J Minim Invasive Gynecol.* 2021;28(11):1849-1859. https://doi.org/10.1016/j.jmig.2021.08.032. Accessed Nov.

24. Bourdel N, Chauvet P, Billone V, et al. Systematic review of quality of life measures in patients with endometriosis. *PLoS One.* 2019;14(1):e0208464. https://doi.org/10.1371/journal.pone.0208464.

25. Leonardi M, Condous G. A pictorial guide to the ultrasound identification and assessment of uterosacral ligaments in women with potential endometriosis. *Australas J Ultrasound Med.* 2019;22(3):157-164. http://dx.doi.org/10.1002/ajum.12178.

26. Fryer J, Mason-Jones AJ, Woodward A. Understanding diagnostic delay for endometriosis: A scoping review using the social-ecological framework. *Health*

Care for Women International. 2024. https://doi.org/10.1080/07399332.2024.2413056.

27. Chen CX, Shieh C, Draucker CB, Carpenter JS. Reasons women do not seek health care for dysmenorrhea. *J Clin Nurs.* 2018;27(1-2):e301-e308. https://doi.org/10.1111/jocn.13946.

28. Frayne J, Milroy T, Simonis M, Lam A. Challenges in diagnosing and managing endometriosis in general practice: A Western Australian qualitative study. *Australian Journal for General Practitioners.* 2023;52:547-555. https://doi.org/10.31128/AJGP-10-22-6579

29. Johnson NP, Hummelshoj L, Consortium ftWESM, et al. Consensus on current management of endometriosis. *Hum Reprod.* 2013;28(6):1552-1568. https://doi.org/10.1093/humrep/det050.

30. Pascoal E, Wessels JM, Aas-Eng MK, et al. Strengths and limitations of diagnostic tools for endometriosis and relevance in diagnostic test accuracy research. *Ultrasound Obstet Gynecol.* 2022. https://doi.org/10.1002/uog.24892.

31. Schenken RS. Endometriosis in adults: Clinical features, evaluation, and diagnosis. 2024. https://www.uptodate.com/contents/endometriosis-in-adults-clinical-features-evaluation-and-diagnosis?search=endometriosis%20diagnosis&source=search_result&selectedTitle=1%7E150&usage_type=default&display_rank=1. Accessed Dec 2024.

32. Loubeyre P, Petignat P, Jacob S, Egger JF, Dubuisson JB, Wenger JM. Anatomic distribution of posterior deeply infiltrating endometriosis on MRI after vaginal and rectal gel opacification. *AJR Am J Roentgenol.* Jun 2009;192(6):1625-1631.

33. Alborzi S, Rasekhi A, Shomali Z, et al. Diagnostic accuracy of magnetic resonance imaging, transvaginal, and transrectal ultrasonography in deep infiltrating endometriosis. *Medicine (Baltimore).* Feb 2018;97(8):e9536.

34. Bazot M, Bharwani N, Huchon C, et al. European society of urogenital radiology (ESUR) guidelines: MR imaging of pelvic endometriosis. *Eur Radiol.* 2017;27(7):2765-2775. http://dx.doi.org/10.1007/s00330-016-4673-z.

35. Chamié LP, Blasbalg R, Pereira RM, Warmbrand G, Serafini PC. Findings of pelvic endometriosis at transvaginal US, MR imaging, and laparoscopy. *Radiographics.* 2011;31(4):E77-100. https://doi.org/10.1148/rg.314105193. Accessed Jul-Aug.

36. Young SW, Groszmann Y, Dahiya N, et al. Sonographer-acquired ultrasound protocol for deep endometriosis. *Abdom Radiol.* 2020;45(6):1659-1669. https://dx.doi.org/10.1007/s00261-019-02341-4.

37. Deslandes A, Panuccio C, Avery J, et al. Are sonographers the future 'gold standard' in the diagnosis of endometriosis? *Sonography.* 2023;n/a(n/a). https://doi.org/10.1002/sono.12402.

38. ASUM. Australasian Society for Ultrasound in Medicine - Guidelines on the Performance of a Gynaecological Ultrasound Examination. https://www.asum.com.au/files/public/SoP/curver/Obs-Gynae/Gynaecological-GL-2020.pdf.

39. Exacoustos C, De Felice G, Pizzo A, et al. Isolated Ovarian Endometrioma: A History Between Myth and Reality. *J Minim Invasive Gynecol.* July - August 2018;25(5):884-891.

40. Abrao MS, Gonçalves MO, Dias JA, Jr., Podgaec S, Chamie LP, Blasbalg R. Comparison between clinical examination, transvaginal sonography and magnetic resonance imaging for the diagnosis of deep endometriosis. *Hum Reprod.* 2007;22(12):3092-3097. https://doi.org/10.1093/humrep/dem187.

41. Frey I, Perrot N. Deep pelvic endometriosis: US features. *Imagerie de la Femme.* 2006;16(3):163-168.

42. Guerriero S, Ajossa S, Gerada M, Virgilio B, Angioni S, Melis GB. Diagnostic value of transvaginal 'tenderness-guided' ultrasonography for the prediction of location of deep endometriosis. *Hum Reprod.* 2008;23(11):2452-2457. http://dx.doi.org/10.1093/humrep/den293.

43. Vimercati A, Achilarre MT, Scardapane A, et al. Accuracy of transvaginal sonography and contrast-enhanced magnetic resonance-colonography for the presurgical staging of deep infiltrating endometriosis. *Ultrasound in obstetrics & gynecology : the official journal of the International Society of Ultrasound in Obstetrics and Gynecology.* Nov 2012;40(5):592-603.

44. Cleveland Clinic, Transvaginal Ultrasound. 2022. https://my.clevelandclinic.org/health/diagnostics/4993-transvaginal-ultrasound.

45. Deslandes A, Parange N, Childs JT, Osborne B, Bezak E. Current Status of Transvaginal Ultrasound Accuracy in the Diagnosis of Deep Infiltrating Endometriosis Before Surgery: A Systematic Review of the Literature. *Journal of ultrasound in medicine : official journal of the American Institute of Ultrasound in Medicine.* 01 Aug 2020;39(8):1477-1490.

46. Gerges B LW, Leonardi M, Mol BW, Condous G. Meta-analysis and systematic review to determine the optimal imaging modality for the detection of uterosacral ligaments/torus uterinus, rectovaginal septum and vaginal deep endometriosis. . *Hum Reprod Open. 2021 Nov 4;2021(4):hoab041. doi: 10.1093/hropen/hoab041. PMID: 34869918; PMCID: PMC8634567.* 2021. https://doi.org/10.1093/hropen/hoab041.

47. Freger SM, Turnbull V, McGowan K, Leonardi M. Prospective diagnostic test accuracy of transvaginal ultrasound posterior approach for uterosacral ligament and torus uterinus deep endometriosis. *Ultrasound Obstet Gynecol.* 2024;63(2):263-270. https://doi.org/10.1002/uog.27492.

48. Guerriero S, Ajossa S, Minguez JA, et al. Accuracy of transvaginal ultrasound for diagnosis of deep endometriosis in uterosacral ligaments, rectovaginal septum, vagina and bladder: systematic review and meta-analysis. *Ultrasound in obstetrics & gynecology : the official journal of the International Society of Ultrasound in Obstetrics and Gynecology.* 2015;46(5):534-545. http://dx.doi.org/10.1002/uog.15667.

49. Guerriero S, Ajossa S, Orozco R, et al. Accuracy of transvaginal ultrasound for diagnosis of deep endometriosis in the rectosigmoid: systematic review and meta-analysis. *Ultrasound Obstet Gynecol.* 2016;47(3):281-289. https://doi.org/10.1002/uog.15662.

50. Edwards C, Thoirs K, Osborne B, et al. Australian sonographer competency—A new framework. *Sonography.* 2022;9(3):108-115. https://doi.org/10.1002/sono.12309.

51. POCUS 101, Gynecology/Pelvic Ultrasound Made Easy: Step-By-Step Guide. 2024.

52. Ultrasoundpaedia. Gynaecology, Ovary normal. 2024. https://ultrasoundpaedia.com/ovary-normal/.

53. Endometriosis Australia. 2024. https://endometriosisaustralia.org.

54. Becker CM, Laufer MR, Stratton P, et al. World Endometriosis Research Foundation Endometriosis Phenome and Biobanking Harmonisation Project: I. Surgical phenotype data collection in endometriosis research. *Fertil Steril.* 2014;102(5):1213-1222. https://doi.org/10.1016/j.fertnstert.2014.07.709.

55. Mardon AK, Leake HB, Hayles C, et al. The Efficacy of Self-Management Strategies for Females with Endometriosis: a Systematic Review. *Reproductive*

Sciences. 2023;30(2):390-407. https://doi.org/10.1007/s43032-022-00952-9. Accessed 2023/02/01.

56. Zhou Y, Su Y, Liu H, Wu H, Xu J, Dong F. Accuracy of transvaginal ultrasound for diagnosis of deep infiltrating endometriosis in the uterosacral ligaments: Systematic review and meta-analysis. *J Gynecol Obstet Hum Reprod.* 2021;50(3). http://dx.doi.org/10.1016/j.jogoh.2020.101953.

57. Bazot M, Lafont C, Rouzier R, Roseau G, Thomassin-Naggara I, Darai E. Diagnostic accuracy of physical examination, transvaginal sonography, rectal endoscopic sonography, and magnetic resonance imaging to diagnose deep infiltrating endometriosis. *Fertility and Sterility.* 2009;92(6):1825-1833. http://dx.doi.org/10.1016/j.fertnstert.2008.09.005.

58. Vu D, Haylen B, Tse K, Farnsworth A. Surgical anatomy of the uterosacral ligament. *International urogynecology journal.* 2010;21:1123-1128. https://doi.org/10.1007/s00192-010-1147-8.

59. Indrielle-Kelly T, Fruhauf F, Fanta M, et al. Diagnostic Accuracy of Ultrasound and MRI in the Mapping of Deep Pelvic Endometriosis Using the International Deep Endometriosis Analysis (IDEA) Consensus. *Biomed Res Int.* 2020;2020:3583989.

60. Chapron C, Fauconnier A, Vieira M, et al. Anatomical distribution of deeply infiltrating endometriosis: surgical implications and proposition for a classification. *Hum Reprod.* 2003;18(1):157-161. https://doi.org/10.1093/humrep/deg009.

61. Scioscia M, Bruni F, Ceccaroni M, Steinkasserer M, Stepniewska A, Minelli L. Distribution of endometriotic lesions in endometriosis stage IV supports the menstrual reflux theory and requires specific preoperative assessment and therapy. *Acta Obstet Gynecol Scand.* 2011;90(2):136-139. https://doi.org/10.1111/j.1600-0412.2010.01008.x.

62. Zhang Y, Xiao X, Xu F, Lin Q, Xu J, Du B. Evaluation of uterosacral ligament involvement in deep endometriosis by transvaginal ultrasonography. *Front Pharmacol.* 2019;10(APR).

63. Guerriero S, Saba L, Pascual MA, et al. Transvaginal ultrasound vs magnetic resonance imaging for diagnosing deep infiltrating endometriosis: systematic review and meta-analysis. *Ultrasound in obstetrics & gynecology : the official journal of the International Society of Ultrasound in Obstetrics and Gynecology.* 01 May 2018;51(5):586-595.

64. Savelli L, Ambrosio M, Salucci P, Raimondo D, Arena A, Seracchioli R. Transvaginal ultrasound features of normal uterosacral ligaments. *Fertility and Sterility.* 2021.

65. Leonardi M, Uzuner C, Mestdagh W, et al. Diagnostic accuracy of transvaginal ultrasound for detection of endometriosis using International Deep Endometriosis Analysis (IDEA) approach: prospective international pilot study. *Ultrasound Obstet Gynecol.* 2022;60(3):404-413. https://doi.org/10.1002/uog.24936.

66. Montanari E, Dauser B, Keckstein J, Kirchner E, Nemeth Z, Hudelist G. Association between disease extent and pain symptoms in patients with deep infiltrating endometriosis. *Reprod Biomed Online.* 2019;39(5):845-851. https://doi.org/10.1016/j.rbmo.2019.06.006.

67. Young SW, Dahiya N, Patel MD, et al. Initial Accuracy of and Learning Curve for Transvaginal Ultrasound with Bowel Preparation for Deep Endometriosis in a US Tertiary Care Center. *J Minim Invasive Gynecol.* 2017;24(7):1170-1176. http://dx.doi.org/10.1016/j.jmig.2017.07.002.

68. Maple S, Chalmers KJ, Bezak E, Henry K, Parange N. Ultrasound Characteristics and Scanning Techniques of Uterosacral Ligaments for the Diagnosis of Endometriosis. *J Ultrasound Med.* 2022;42(6):1193-1209. https://doi.org/10.1002/jum.16129.

69. Maple S, Bezak E, Chalmers KJ, Parange N. Ultrasound of the Uterosacral Ligaments: A Reliability Study for Diagnosing Endometriosis in Australian Non-Specialised Medical Imaging and Radiology Settings. *Australas J Ultrasound Med.* 2025;28(1):e12420. https://doi.org/10.1002/ajum.12420.

70. Maple S, Bezak E, Chalmers KJ, Parange N. Relationship Between Ultrasound Diagnosis, Symptoms and Pain Scale Score on Examination in Patients with Uterosacral Ligament Endometriosis. *J.* 2024;13(22):6901. https://doi.org/10.3390/jcm13226901.

71. Kamkarfar P, Shahriyaripoor R, Rokhgireh S, Saadat Mostafavi SR, Chaichian S, Mehdizadeh Kashi A. Comparison of diagnostic values of transvaginal sonography with laparoscopic and histological results in the evaluation of uterosacral ligaments' involvement in endometriosis patients. *Caspian Journal of Internal Medicine.* 2022;13(4):705-712. http://10.22088/cjim.13.4.705.

72. Martire FG, Russo C, Selntigia A, et al. Early noninvasive diagnosis of endometriosis: dysmenorrhea and specific ultrasound findings are important indicators in young women. *Fertility and Sterility.* 2023;119(3):455-464. https://doi.org/10.1016/j.fertnstert.2022.12.004.

73. Roditis A, Florin M, Rousset P, et al. Accuracy of combined physical examination, transvaginal ultrasonography, and magnetic resonance imaging to diagnose deep endometriosis. *Fertility and Sterility.* 2023;119(4):634-643. https://doi.org/10.1016/j.fertnstert.2022.12.025.

74. Fernandez CM, Levine EM, Shashoua A, Tam MT, Diaz L. The expanding role of sonography for the diagnosis of deep infiltrating endometriosis: Results of a large case series. *International Journal of Gynecology & Obstetrics.* 2024;166(1):326-332. https://doi.org/10.1002/ijgo.15418.

75. Chen Q, Jia L, Wang S, et al. Douglas Pouch Fluid Improves the Accuracy of Transvaginal Ultrasound in the Diagnosis of Uterosacral Ligaments Deep Infiltration Endometriosis. *J Ultrasound Med.* 2024;n/a(n/a). https://doi.org/10.1002/jum.16586.

76. AIUM Practice Parameter for the Performance of an Ultrasound Examination of the Female Pelvis. *J Ultrasound Med.* 2020;39(5):E17-e23. https://10.1002/jum.15205.

77. Spiers A, Roman H, Wasson M, et al. Clues to revising the conventional diagnostic algorithm for endometriosis. *International Journal of Gynecology & Obstetrics.* 2024;n/a(n/a). https://doi.org/10.1002/ijgo.15840.

78. Robinson AJ, Rombauts L, Ades A, Leong K, Paul E, Piessens S. Poor sensitivity of transvaginal ultrasound markers in diagnosis of superficial endometriosis of the uterosacral ligaments. *Journal of Endometriosis and Pelvic Pain Disorders.* 01 Mar 2018;10(1):10-17.

79. Chowdary P, Stone K, Ma T, et al. Multicentre retrospective study to assess diagnostic accuracy of ultrasound for superficial endometriosis-Are we any closer? *Australian and New Zealand Journal of Obstetrics and Gynaecology.* 2019;59(2):279-284. http://dx.doi.org/10.1111/ajo.12911.

80. Kottner J, Audige L, Brorson S, et al. Guidelines for Reporting Reliability and Agreement Studies (GRRAS) were proposed. *Int J Nurs Stud.* 2011;48(6):661-671. https://doi.org/10.1016/j.ijnurstu.2011.01.016.

81. Cuschieri S. The STROBE guidelines. *Saudi J Anaesth.* 2019;13(Suppl 1):S31-s34. https://doi.org/10.4103/sja.SJA_543_18.

82. Jean Hailes 2023 National Women's Health Survery. Pelvic Pain in Australian Women. 2023. https://www.jeanhailes.org.au/research/womens-health-survey/pelvic-pain-in-australian-women.

Appendix

Appendix 1: Systematic Review Search Strategy

Appendix 2: Data Collection - *Observer Questionnaire*

Appendix 3: Data Collection - *SST Scoring Matrix*

Appendix 4: Data Collection - *McGill Pain Scale questionnaire used to develop the SST data collection template*

Appendix 5: Raw Data - *USL Images: patient participant data collection*

Appendix 6: Raw Data - *SST Score: patient participant data collection*

Appendix 7: Ethics Completion

Appendix 8: Statement of Authorship - *Ultrasound characteristics and scanning techniques of uterosacral ligaments for the diagnosis of endometriosis: A Systematic Review*

Appendix 9: Statement of Authorship - *Ultrasound of the Uterosacral Ligaments: A Reliability Study for Diagnosing Endometriosis in Australian Non-Specialised Medical Imaging and Radiology Settings*

Appendix 10: Statement of Authorship - *Relationship Between Ultrasound Diagnosis, Symptoms and Pain Scale Score on Examination in Patients with Uterosacral Ligament Endometriosis*

Ultrasound characteristics and scanning technique of uterosacral ligaments for diagnosis of endometriosis: systematic review

MEDLNE search strategy

1. Endometriosis.mp or Endometriosis/
2. Endometrio*.mp
3. "Deep infiltrating".mp
4. "Infiltrating Endometriosis".mp
5. "Superficial endometriosis".mp
6. "superficial endometrio*".mp
7. "infiltrating endometrio*".mp
8. DIE.mp
9. DIE/
10. SE
11. "Uterosacral ligament*".mp
12. USL.mp
13. OR 1-10
14. 11 OR 12
15. 12 AND 14
16. Ultrasound.mp
17. Ultrasonography/ or "endosonography/
18. Sonog*.mp
19. Transvaginal*.mp
20. Endovaginal*.mp
21. Sonopodography.mp
22. OR 16-21
23. 15 AND 22

Observer Questions

for interobservational agreement

	Question	Normal USL Answer	DE USL Answer	DE Nodule Answer	Notes
Question 1	Echogenicity of USL?	Hyperechoic and/or Homogeneous	Heterogeneous	Hypoechoic	Multiple choice – can choose multiple answers Hypoechoic, Heterogeneous, Hyperechoic and/or Homogeneous
Question 2	Contour of USL?	Smooth Margins	Irregular margins	-	Multiple choice – can only choose one Smooth or Irregular margins
Question 3	Do you see an endometriotic nodule at the USL? (can select multiple)	No	Yes or No	Yes / Solid Mass	Yes or no – only choose one
Question 3b (if applicable)	If **YES** to endometriotic nodule, what is the contour of nodule?	N/A	N/A	→	Multiple choice – one option only Smooth/regular margins Irregular margins Stellate margins
Question 4	Thickness (subjectively)	USL Thin	USL Thickened	USL Thickened	Multiple choice – one option only Not thickened/thin Thickened
Question 5	Where in your opinion is the best site for measurement of USL?	Free text box			
Question 6	In your opinion, does this USL appear normal or abnormal?	Normal	Abnormal	Abnormal	Multiple choice – Normal, Abnormal, Unsure

The observer will have a still image and a cine clip of USLs for each participant (n=42).

University of South Australia

SST Data Collection Sheet

Title	Ultrasound characteristics and measurements of uterosacral ligaments for diagnosis of deep infiltrating endometriosis with MRI and surgical correlation
Principal Investigator	Shae Maple
Associate Investigators	Associate Professor Nayana Parange, Professor Eva Bezak, Dr Jane Chalmers

Participant ID: _____ Date: _____

Persistent Pain Index (PPI) & Pain Rating Index (PRI)

PPI: For each SST ask: "Can you tell me how painful this spot is on a scale of 0-10 where 0 represents no pain and 10 represents the worst pain imaginable?"

PRI: For each SST ask: "can you describe what the pain feels like?"

PPI Severity Rating

SST / PRI	Nil	Mild Discomfort		Discomfort		Distressing		Horrible		Excruciating	
Rt USL	0	1	2	3	4	5	6	7	8	9	10
	Tender	Dull Ache		Cramping		Sharp		Bloating		Stabbing	Other
Lt USL	0	1	2	3	4	5	6	7	8	9	10
	Tender	Dull Ache		Cramping		Sharp		Bloating		Stabbing	Other
Rt Ovary	0	1	2	3	4	5	6	7	8	9	10
	Tender	Dull Ache		Cramping		Sharp		Bloating		Stabbing	Other
Lt Ovary	0	1	2	3	4	5	6	7	8	9	10
	Tender	Dull Ache		Cramping		Sharp		Bloating		Stabbing	Other
Post Fornix	0	1	2	3	4	5	6	7	8	9	10
	Tender	Dull Ache		Cramping		Sharp		Bloating		Stabbing	Other
POD	0	1	2	3	4	5	6	7	8	9	10
	Tender	Dull Ache		Cramping		Sharp		Bloating		Stabbing	Other
Bladder	0	1	2	3	4	5	6	7	8	9	10
	Tender	Dull Ache		Cramping		Sharp		Bloating		Stabbing	Other
Other											

Appendix 5 - McGill Pain Scale questionnaire used to develop the SST data collection template.

McGILL PAIN QUESTIONNAIRE

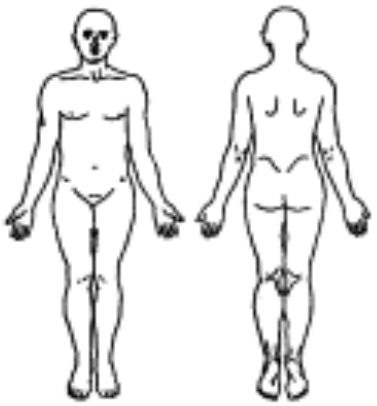
RONALD MELZACK

Patient's Name _____ Date _____ Time _____ am/pm

PRI: S _____ A _____ E _____ M _____ PRI(T) _____ PPI _____
(1-10) (11-15) (16) (17-20) (1-20)

1 FLICKERING	11 TIRING	
QUIVERING	EXHAUSTING	
PULSING	12 SICKENING	
THROBBING	SUFFOCATING	
BEATING	13 FEARFUL	
POUNDING	FRIGHTFUL	
2 JUMPING	TERRIFYING	
FLASHING	14 PUNISHING	
SHOOTING	GRUELLING	
3 PRICKING	CRUEL	
BORING	VICIOUS	
DRILLING	KILLING	
STABBING	15 WRETCHED	
LANCINATING	BLINDING	
4 SHARP	16 ANNOYING	
CUTTING	TROUBLESOME	
LACERATING	MISERABLE	
5 PINCHING	INTENSE	
PRESSING	UNBEARABLE	
GNAWING	17 SPREADING	
CRAMPING	RADIATING	
CRUSHING	PENETRATING	
6 TUGGING	PIERCING	
PULLING	18 TIGHT	
WRENCHING	NUMB	
7 HOT	DRAWING	
BURNING	SQUEEZING	
SCALDING	TEARING	
SEARING	19 COOL	
8 TINGLING	COLD	
ITCHY	FREEZING	
SMARTING	20 NAGGING	
STINGING	NAUSEATING	
9 DULL	AGONIZING	
SORE	DREADFUL	
HURTING	TORTURING	
ACHING	PPI	
HEAVY	0 NO PAIN	
10 TENDER	1 MILD	
TAUT	2 DISCOMFORTING	
RASPING	3 DISTRESSING	
SPLITTING	4 HORRIBLE	
	5 EXCRUCIATING	

BRIEF	RHYTHMIC	CONTINUOUS
MOMENTARY	PERIODIC	STEADY
TRANSIENT	INTERMITTENT	CONSTANT



E = EXTERNAL
I = INTERNAL

COMMENTS:

Patient ID	Endometriosis Hx				Edndometriosis Symptoms				Ultrasound Findings (Endometriosis)							USL Findings				USL Measurement	OTHER US Located Endometriotic Lesion
	Nil Hx	Yes (Lap)	Yes (Clin)	Susp (Clin)	Chronic Pelvic Pain	Dysmenorrhea	Infertility	Dysparunisa	Adenomyeosis	Obliterated POD	Retroverted/ Retroflexed Uterus	Endometrioma	Adherent Ovaries	Kissing Ovaries	Bowel Lesions	USL Nodule	Heterogeneous/ Hypoechoic	Irregular Margins	Thickened	(mm)	(not USL)
USLSM01		√			√	√					√		√	√			√	√	√	6.6mm	
USLSM02	√	-	-	-	-	-	-	-	√	-	-		-	-	-	-	-	-	-	<3	
USLSM03				√		√				√	√		√		√	√	√	√	√	6.4mm	Retrocervical Nodule
USLSM04	√	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	<3	
USLSM05		√			√	√		√	√		√		√		√		√	√	√	6mm	Rectosigmoid Bowel Nodule
USLSM06		√				√		√	√			√	√	√			√	√	√	5.1mm	
USLSM07	√	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<3	
USLSM08	√	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<3	
USLSM09	√	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<3	
USLSM10	√	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<3	
USLSM11			√		√	√			√				√		√		√	√	√	5mm	LSCS Scar Endo
USLSM12			√		√					√	√	√	√	√	√	√	√	√	√	5.5mm	Rectosigmoid Bowel Nodule + Seroaal Plaques
USLSM13		√			√		√				√				√	√	√	√	√	4.3mm	Rectocervial Nodule
USLSM14	√	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<3	
USLSM15				√		√			√			√					√		√	4.2mm	
USLSM16	√	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<3	
USLSM17			√		√	√			√								√		√	4.2mm	
USLSM18	√	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.9mm	
USLSM19				√	√				√				√				√	√	√	5.3mm	
USLSM20				√	√		√		√		√				√	√	√	√		3.4mm, then tapers/adheres	Retrocervical Nodule (RVS)
USLSM21		√			√				√	√	√	√	√	√	√		√	√	√	9.2mm	Rectosigmoid Bowel Nodule + Serosal Plaques
USLSM22				√	√	√						√	√		√		√		√	4.7mm	Rectocervial Nodule
USLSM23			√		√	√							√	√	√	√	√	√	√	3.7mm	Rectosigmoid Bowel Nodule
USLSM24	√	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.4mm	
USLSM25				√		√	√		√						√		√	√	√	4.6mm	(#) Retrocervical Plaque
USLSM26			√		√	√			√				√		√	√	√	√	√	8.6mm	
USLSM27		√			√	√			√	√	√	√	√	√	√	√	√	√	√	7.8mm	Upper Rectal Bowel Nodule
USLSM28		√			√				√		√		√				√	√	√	3.6mm	
USLSM29			√		√				√			√	√				√	√	√	7.8mm	
USLSM30		√			√	√						√	√				√	√	√	5.8mm	
USLSM31				√	√		√		√		√				√		√	√	√	4.8mm	Rectosigmoid Bowel Nodule
USLSM32	√	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5mm	
USLSM33	√	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.1mm	
USLSM34			√		√										√	√	√	√	√	5mm	
USLSM35				√	√	√		√				√	√		√	√	√	√	√	6.4mm	Retrocervical Nodule
USLSM36		√			√		√	√	√		√	√	√	√	√	√	√	√	√	8.5mm	
USLSM37				√	√	√			√						√		√	√	√	6.5mm	Bowel Nodule
USLSM38				√	√				√			√	√		√		√	√	√	6.2mm	Rectocervial Nodule
USLSM39		√			√							√	√		√	√	√	√	√	7mm	Retrocervical Nodule
USLSM40				√	√		√		√			√	√	√	√		√	√	√	5.2mm	
USLSM41				√	√	√							√	√	√	√	√	√	√	5.2mm	Retrocervical Nodule
USLSM42				√	√			√				√					√	√	√	5.1mm	

Key:	No DE	Hx DE

Patient ID	Endo Hx	R USL			L USL			R Ovary			L Ovary			Post Fornix			POD			Bladder			Other		
		US	PPI (0-10)	PRI	US	PPI (0-10)	PRI	US	PPI (0-10)	PRI	US	PPI (0-10)	PRI	US	PPI (0-10)	PRI	US	PPI (0-10)	PRI	US	PPI (0-10)	PRI	US	PPI (0-10)	PRI
USLSM01	√		3	Tender		3	Tender		7	Sharp		7	Sharp		8	Sharp		6	Sharp						
USLSM02	N Hx																								
USLSM03	√	Nodule	8	Sharp		1	Tender	Adhered	6	Sharp	Adhered	6	Sharp	UT Rotated	6	Sharp	Obterated	7	Sharp		0				
USLSM04	N Hx																								
USLSM05	√		4	Sharp		4	Sharp	Adhered	5	Sharp	Adhered	5	Sharp	UT Retroverted	4	Pressure		3	Du Ache		5	Stabbing	Bowe Nodule	10	Sharp Stabbing
USLSM06	√		0			0		Adhered / ?Endometroma	5	Du Ache	Adhered	6	Du Ache		1	Pressure		0			0				
USLSM07	N Hx											1	Tender												
USLSM08	N Hx		4	Tender								4	Tender												
USLSM09	N Hx																								
USLSM10	N Hx																								
USLSM11	√		1	Du Ache		1	Du Ache	Adhered	4	Sharp	Adhered	6	Sharp		0			0			0		LSCS Nodule	10	Sharp
USLSM12	√	Paque/Tethering	5	Sharp		5	Sharp	Adhered/Mdase d + Endometroma	5	Du Ache	Adhered/Mdase d + Endometroma	4	Du Ache	Tethered Paque	1	Du Ache	Obterated	6	Du Ache		0		Bowe Lesons	6	Sharp
USLSM13	√		9	Sharp	Nodule	10	Sharp		6	Du Ache		6	Du Ache	UT Retroverted	9	Du Ache		9	Sharp		5	Du Ache	Bowe / LUSL Lesion	10	Sharp
USLSM14	N Hx																								
USLSM15	√		5	Sharp		5	Sharp	Endometroma	3	Du Ache		3	Du Ache		5	Du Ache		0			0				
USLSM16	N Hx																								
USLSM17	√		2	Du Ache		2	Du Ache		3	Du Ache		0			4	Du Ache		4	Du Ache		0				
USLSM18	N Hx																								
USLSM19	√		0			3	Du Ache		0		Adhere	3	Du Ache		2	Du Ache		0			0				
USLSM20	√	Nodule/Tethered	10	Sharp		2	Du Ache		1	Tender		1	Tender	UT Retroverted	8	Sharp		8	Sharp		0		RVS/Bowe Nodue	10	Sharp
USLSM21	√		4	Tender/Ache		4	TenderAche	Adhered/Mdase d + Endometroma	9	Sharp	Adhered/Mdase d	8	Sharp	Nodule	8	Sharp	Obterated	9	Sharp		4	Du Ache	Uterine Serosa		
USLSM22	√		6	Sharp		9	Sharp	Endometroma	6	Adhered		8	Sharp	Nodule	9	Sharp		8	Sharp		0		RVS/Bowe Nodue	10	Sharp
USLSM23	√		8	Sharp	Nodule	9	Sharp	Adhered/Mdased	6	Sharp	Adhered/Mdased	8	Sharp	Nodule	9	Sharp		8	Sharp	0			Bowe Nodule	10	Sharp
USLSM24	N Hx														4	Tender									
USLSM25	√		6	Tender		6	Tender		4	Tender		6	Tender		5	Tender		0			0		Rettocerv ca Paque	9	Sharp
USLSM26	√		5		Nodule	10	Sharp		0		Adhered/Mdased	10	Sharp		7	Sharp		0			0				
USLSM27	√	Nodule/Theth erec	8	Du Ache	Nodule/Tethered	8	Du Ache	Adhered/Mdase d	9	Sharp	Adhered/Mdase d + Endometroma	9	Sharp	UT Retroverted	8	Du Ache	Obterated	8	Du Ache		2	Tender	Recta /Bowe Nodule	9	Sharp
USLSM28	√		1	Tender		1	Tender	Adhered	9	Sharp		5	Du Ache	UT Retroverted	4	Tender		0			0				
USLSM29	√		5	Du Ache		5	Du Ache		6	Sharp	Adhered/Mdase d + Endometroma	7	Sharp		5	Du Ache		5	Du Ache		7	Sharp			
USLSM30	√		6	Sharp		2	Du Ache	Adhered	6	Sharp	Adhered	7	Sharp		6	Du Ache		0			0				
USLSM31	√		2	Du Ache		2	Du Ache		2	Du Ache		2	Du Ache	UT Retroverted	7	Du Ache		2	Du Ache		0		Recta /Bowe Nodule	10	Sharp
USLSM32	N Hx																								
USLSM33	N Hx											6	Tender/Du Ache		6	Tender/Du Ache									
USLSM34	√		6	Du Ache	Nodule	8	Sharp		3	Du Ache		6	Du Ache		8	Sharp		0			0		Nodule	10	Sharp
USLSM35	√	Nodule	10	Sharp		5	Du Ache	Adhered	9	Sharp/Stabbing		8	Sharp	RetrocervaL Paque	9	Sharp		3	Du Ache		3	Du Ache	Retrocerv ca Nodule	10	Sharp
USLSM36	√		8	Sharp	Nodule	9	Sharp	Adhered/Mdase d + Endometroma	7	Sharp	Adhered/Mdase d	8	Sharp		2	Tender		2	Tender		0				
USLSM37	√		8	Sharp		10	Sharp		8	Du Ache		8	Du Ache		7	Du Ache		6	Du Ache		0		Bowe Nodule	10	Sharp
USLSM38	√		9	Sharp		2	Tender	Adhered / ?Endometroma	10	Sharp/Stabbing	Adhered/Mdase d	8	Sharp		9	Sharp/Stabbing		8	Sharp		0		Retrocerv ca Nodule	10	Sharp
USLSM39	√	Nodule	8	Stabbing	Nodule	8	Stabbn	Adhered/Mdase d + Endometroma	7	Stabbing		6	Du Ache		8	Stabbing		4	Du Ache		0		Retrocerv ca Nodule	10	Stabbing
USLSM40	√		8	Sharp		8	Sharp	hered / ?Endometro	7	Sharp	Adhered	7	Sharp		8	Sharp		6	Sharp		0				
USLSM41	√		6	Du Ache	Nodule	8	Sharp		4	Du Ache	Adhered/Mdased	7	Sharp		7	Sharp		6	Sharp		3	Tender	Retrocerv ca Nodule	9	Sharp
USLSM42	√		6	Sharp		5	Sharp	Endometroma	7	Sharp		5	Du Ache		2	Tender		2	Tender		0	1			

Key:	No DE	Hx DE

SECTION 1: PROJECT DETAILS			
Chief Investigator	Shae Maple		
Project Title	TRANSVAGINAL ULTRASOUND OF THE UTEROSACRAL LIGAMENTS FOR THE DIAGNOSIS OF DEEP ENDOMETRIOSIS		
Project Number	204237	Original Approval Date	4/11/21

APPROVAL FROM NON-UNISA HREC	
Does this project have non-UniSA HREC ethics approval?	
☐ Yes – *please attach a copy of the approval from the Primary HREC for the annual report or approved extension request*	☒ No

SECTION 2: PROJECT STATUS – Please select your reason for completing this form			
Status	**Select**	**Indicate Date**	**Instruction**
In Progress	☐	Anticipated Date of completion:	Go to Section 5
Extension Required	☐	Anticipated Date of completion (*maximum 1 additional year)*:	Go to Section 5
Discontinued / Not commenced	☐	Date work was stopped:	Go to Section 3
Completed	☒	Date of completion: 4/10/24	Go to Section 4

SECTION 4: COMPLETED PROJECTS –

Section 4.1 List original aims of the project (from the original approved application):

The primary objective of this research project is to identify ultrasound characteristics and measurements of uterosacral ligaments in the diagnosis of endometriosis.

Section 4.2 Were the aims of the project achieved? Provide a brief summary of the findings to date below: ☒ Yes ☐ No

This project investigated the ultrasound techniques and characteristics of normal and abnormal USLs in the diagnosis of endometriosis and associated site-specific tenderness and pain scale descriptors into the TVS diagnosis for DE to assess if there is diagnostic benefit, with consideration between experienced and less experienced examiners in a general ultrasound imaging practice.

Firstly, a systematic review identified that published literature reporting ultrasound criteria of DE shows descriptive reporting only with no interobservational or intraobservational validation with inconsistent descriptors and varying terminology. Data was from tertiary centres therefore cannot be applied to a general setting. There needs to be clear and reproducible ultrasound criteria to improve reporting standardisation of the diagnosis of endometriosis as well as sonographer and radiologist education in general settings.
Following this, the second interrater study established high interobserver agreement of sonographers and radiologists in a general imaging department for identifying ultrasound characteristics for USLs and diagnosing DE of the USLs and has shown that there is consistency in identifying a thickened USL. However, there is no consensus on where USL be measured. Even so, a thickened USL can prompt further extension of the pelvic scan to look for other markers of endometriosis.
Finally, the findings of the third observational study demonstrated that patients with endometriosis history do have significantly higher pain scores on TVS compared to patients with no history of endometriosis. Inclusion of SST to TVS shows promise in diagnosis of endometriosis, with a higher ability to correctly identify endometriosis with the pain scale information. However, this needs to be interpreted with caution as not statically significant.

Section 4.3 Have study participants been informed of the results? Provide details.	☐ Yes	☐ No	☒ N/A

Go to Section 7

SECTION 7: CLINICAL TRIALS

Complete this section if this study is a clinical trial only, otherwise go to Section 8.

Please note that section 5.5.9 of the National Statement states that it may be unethical for a researcher to continue a clinical trial if:

a) there are or have been substantial deviations from the trial protocol;
b) adverse effects of unexpected type, severity, or frequency are encountered; or
c) as the trial progresses, the continuation of the trial would disadvantage some of the participants as determined by the researchers or others monitoring the trial.

Section 7.1 Tick one of the following for this study:

☐ Clinical trial with full industry sponsorship
☐ Clinical trial with sponsorship from a collaborative or non-profit group
☐ Clinical trial initiated by the Chief Investigator

Section 7.2 Is this study being conducted under either the:

Clinical Trial Notification (CTN) Scheme	☐ Yes	☐ No
Clinical Trial Approval (CTA) Scheme	☐ Yes	☐ No

Section 7.3 Does the study have a Data Safety Monitoring Committee (or similar) which has reviewed the study in the past 12 months? If yes, attach a copy of the Committee's report and describe the potential impact on ethical acceptability and the need for action.

Section 7.4 If a safety report is not available, is action planned on the basis of any safety information received in the last 12 months? If yes, describe the potential impact on ethical acceptability and the need for action.	☐ Yes	☐ No

Section 7.5 Has the trial been registered on a publicly accessible register complying with international standards? If yes please provide the names of register(s) and **registration number(s).**	☐ Yes	☐ No

SECTION 8: ETHICAL ISSUES

Tick YES or NO to the following questions.

Section 8.1 Have you departed at all from the approved project? If 'YES' provide details below and confirm if a Project Variation form has been submitted for approval of these changes. If you have departed from the approved project and a Project Variation form has NOT been submitted, complete and submit the Project Variation form for approval.	☐ Yes	☒ No

Section 8.2 Did any participants withdraw from the project during this year? If 'YES', provide details below:	☐ Yes	☒ No	☐ N/A

Section 8.3 Did any ethical implications arise during the research? If 'YES' provide details below, including whether or not they were foreseen, and how they were resolved		☐ Yes	☒ No
Section 8.4 Have any participants suffered harm or adverse effects? If YES, provide the date reported to UniSA HREC? If not provide details as to why not and submit the reports.	☐ Yes	☒ No	☐ N/A
Section 8.5 Have any complaints been received regarding the project? If 'YES' provide the date, source and nature of the complaint, actions taken, and the current status (resolved/in process/other). Include the date UniSA HREC or detail why no notification occurred.		☐ Yes	☒ No
Section 8.6 Has the project been audited by the sponsor, the Human Research Ethics Office or any other body since the last progress report was submitted? If YES, provide details.		☐ Yes	☒ No
COMPLETE THE FOLLOWING 2 QUESTIONS ONLY IF YOU HAVE CONDUCTED RESEARCH IN A COUNTRY OTHER THAN AUSTRALIA-			
Section 8.7 Did you identify any legal, ethical, governmental or other local requirements that you needed to meet? If YES, provide details.		☐ Yes	☒ No
Section 8.8 Did you meet all such requirements and has written evidence been provided to the ethics office? If YES, provide details. If not, provide details as to why written evidence has not yet been submitted and provide a copy of the relevant document(s).	☐ Yes	☐ No	☒ N/A

SECTION 9: DATA STORAGE *Please note: Data must be stored as specified in the approved project. All data must eventually be destroyed, unless explicit consent is obtained from the participants to archive their data.*
Section 9.1 State how and where your data is being stored. Have all records (including data) been maintained in a manner consistent with the arrangements and security measures that were proposed in the approved application? If NO, provide details and submit the Project Variation form for approval
YES. Digital data is held on the principal investigators password protected computer.
Section 9.2 How long will the data be kept after the end of the project?
On completion of the project the research data will be transferred to Research Data Storage Infrastructure and retained for five years as required by South Australian legislation. Purposeful research data that may be relevant to future work on this project will be stored only in secure UniSA endorsed locations accessible by the research collaborators for the minimum period specified by UniSA policy.

Section 9.3 Has there been any breach of confidentiality or data security issues, which includes identifying information? If 'YES' provide details of actions to remedy the breach, including date reported to UniSA HREC or reasons why it was not reported	☐ Yes	☒ No

SECTION 10: DECLARATION

☒ I confirm that the research has been undertaken as per the approved project.

[redacted] *Chief Investigator Signature*	Shae Maple *Printed Name*	4/10/24 *Date*
[redacted] *Supervisor's Signature (students only)*	Nayana Parange *Printed Name*	4th Oct 2024 *Date*

University of South Australia

Statement of Authorship

Title of Paper	Ultrasound Characteristics and Scanning Techniques of Uterosacral Ligaments for the Diagnosis of Endometriosis. A Systematic Review
Publication Status	☐ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details Relevant reference details	Maple, S., Chalmers, K.J., Bezak, E., Henry, K. and Parange, N. (2023), ***Ultrasound Characteristics and Scanning Techniques of Uterosacral Ligaments for the Diagnosis of Endometriosis.*** J Ultrasound Med, 42: 1193-1209. https://doi.org/10.1002/jum.16129

PRINCIPAL AUTHOR

Name of Principal Author (Candidate)	Shae Maple	
Contribution to the Paper Brief description of your work in this publication	Study design, data collection, data analysis, writing and reviewing.	
Overall Percentage (%)	60%	
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.	
Signature *Signatures will be redacted by the Library at the time of publication*	. [redacted]	Date 20/11/2024

CO-AUTHOR CONTRIBUTIONS

By signing the Statement of Authorship, each author certifies that:

I. the candidate's stated contribution to the publication is accurate (as detailed above);

II. permission is granted for the candidate in include the publication in the thesis; and

III. the sum of all co-author contribution is equal to 100% less the candidate's stated contribution.

University of South Australia

Name of Co-Author 1	Professor Nayana Parange	
% Contribution to the Paper		
Signature *Signatures will be redacted by the Library at the time of publication*	[redacted]	Date 28/11/2024
Name of Co-Author 2	Professor Eva Bezak	
% Contribution to the Paper	10%	
Signature *Signatures will be redacted by the Library at the time of publication*	[redacted]	Date: 2/12/2024
Name of Co-Author 3	Dr K Jane Chalmers	
% Contribution to the Paper	15%	
Signature *Signatures will be redacted by the Library at the time of publication*	[redacted]	Date 5/12/2024
Name of Co-Author 4	Katelyn Henry	
% Contribution to the Paper	5%	
Signature *Signatures will be redacted by the Library at the time of publication*	[redacted]	Date 12/2/2025

University of South Australia

Statement of Authorship

Title of Paper	Ultrasound of the Uterosacral Ligaments: A Reliability Study for Diagnosing Endometriosis in Australian Non-Specialised Medical Imaging and Radiology Settings
Publication Status	☐ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details Relevant reference details	Maple, S., Bezak, E., Chalmers, K.J., and Parange, N. (2025), ***Ultrasound of the Uterosacral Ligaments: A Reliability Study for Diagnosing Endometriosis in Australian Non-Specialised Medical Imaging and Radiology Settings.*** Australas J Ultrasound Med, 28: e12420. **2025;** https://doi.org/10.1002/ajum.12420

PRINCIPAL AUTHOR

Name of Principal Author (Candidate)	Shae Maple	
Contribution to the Paper Brief description of your work in this publication	This is an original publication outlining research conducted for my masters thesis with work load including study design, ultrasound scanning and image collection of patient participants, data collection, data analysis, writing and reviewing.	
Overall Percentage (%)	65%	
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.	
Signature *Signatures will be redacted by the Library at the time of publication*	[redacted]	Date 20/11/2024

CO-AUTHOR CONTRIBUTIONS

By signing the Statement of Authorship, each author certifies that:

I. the candidate's stated contribution to the publication is accurate (as detailed above);

II. permission is granted for the candidate in include the publication in the thesis; and

III. the sum of all co-author contribution is equal to 100% less the candidate's stated contribution.

University of South Australia

Name of Co-Author 1	Professor Nayana Parange	
% Contribution to the Paper	15%	
Signature *Signatures will be redacted by the Library at the time of publication*	[redacted]	Date 28/11/2024
Name of Co-Author 2	Professor Eva Bezak	
% Contribution to the Paper	10%	
Signature *Signatures will be redacted by the Library at the time of publication*	[redacted]	Date: 2/12/2024
Name of Co-Author 3	Dr K Jane Chalmers	
% Contribution to the Paper	10%	
Signature *Signatures will be redacted by the Library at the time of publication*	[redacted]	Date 5/12/2024

University of South Australia

Statement of Authorship

Title of Paper	Relationship Between Ultrasound Diagnosis, Symptoms and Pain Scale Score on Examination in Patients with Uterosacral Ligament Endometriosis
Publication Status	☐ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details Relevant reference details	Maple S, Bezak E, Chalmers KJ, Parange N. ***Relationship Between Ultrasound Diagnosis, Symptoms and Pain Scale Score on Examination in Patients with Uterosacral Ligament Endometriosis.*** *Journal of Clinical Medicine*. 2024; 13(22):6901. https://doi.org/10.3390/jcm13226901
PRINCIPAL AUTHOR	
Name of Principal Author (Candidate)	Shae Maple
Contribution to the Paper Brief description of your work in this publication	This is an original publication outlining research conducted for my masters thesis with work load including study design, ultrasound scanning and image collection of patient participants, data collection, data analysis, writing and reviewing.
Overall Percentage (%)	65%
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.
Signature *Signatures will be redacted by the Library at the time of publication*	[redacted] Date 20/11/2024
CO-AUTHOR CONTRIBUTIONS	

By signing the Statement of Authorship, each author certifies that:

I. the candidate's stated contribution to the publication is accurate (as detailed above);

II. permission is granted for the candidate in include the publication in the thesis; and

III. the sum of all co-author contribution is equal to 100% less the candidate's stated contribution.

University of South Australia

Name of Co-Author 1	Professor Nayana Parange	
% Contribution to the Paper	15%	
Signature *Signatures will be redacted by the Library at the time of publication*	[redacted]	Date 28/11/2024
Name of Co-Author 2	Professor Eva Bezak	
% Contribution to the Paper	10%	
Signature *Signatures will be redacted by the Library at the time of publication*	[redacted]	Date: 2/12/2024
Name of Co-Author 3	Dr K Jane Chalmers	
% Contribution to the Paper	10%	
Signature *Signatures will be redacted by the Library at the time of publication*	[redacted]	Date 5/12/2024