

The accuracy of bowel ultrasound in detecting inflammatory bowel disease

by

Amanda Hendricks

A dissertation submitted in fulfilment of the requirements for the degree

MASTER OF RADIOGRAPHY

Department of Clinical Sciences

Faculty of Health and Environmental Sciences

Central University of Technology, Free State

BLOEMFONTEIN

Supervisor: Dr Henra Muller

Co-supervisor: Ms Ferial Isaacs

August 2024

Declaration

I, Amanda Hendricks, declare that this dissertation, entitled *The accuracy of bowel ultrasound in detecting inflammatory bowel disease*, is a presentation of my own original research work conducted at the Central University of Technology, Free State. Wherever contributions from others were involved, every effort has been made to indicate this clearly, with due reference to the literature and acknowledgement of collaborative research and discussions. No part of this dissertation has been submitted for any other degree or professional qualification.

The work was conducted under the guidance of Dr Henra Muller [supervisor] and Ms Ferial Isaacs [co-supervisor].

Amanda Hendricks

May 2024

I certify that the above statement is correct.

Supervisor: Dr Henra Muller

Acknowledgements

A very special thanks to Dr Henra Muller, my main supervisor, who helped to meticulously check my work, pointed out new directions for research and guided me to a stronger conclusion. Thank you for your inspiration and believing in me.

I would like to acknowledge and give my warmest thanks to my co-supervisor, Ms Ferial Isaacs, for her constructive feedback and mentorship throughout.

I also want to extend my heartfelt thanks to Prof. Annabel Fossey, for her enduring support, academic advice and much-appreciated guidance throughout my study.

The Clinical Imaging Sciences Department, Prof. Jacques Janse van Rensburg, and the Department of Gastroenterology, as well as the private hospital, also receive my deepest gratitude for granting me access and permitting me to conduct the study. Special thanks go to Dr Wayne Simmonds for his support and guidance with the study.

A special thank you also to each of the participating patients, for giving consent and participating in the study.

I would also like to give special thanks to my husband and my family, for their continuous support and understanding during this research journey. Your prayers have sustained me this far.

Finally, I would like to thank God for guiding me through all the difficult times during my studies. I will always keep on trusting You for my future.

Table of Contents

Declaration.....	i
Acknowledgements.....	ii
Table of Contents.....	iii
List of Tables	vi
List of Figures	vii
Abbreviations	viii
List of Definitions.....	ix
Abstract.....	x
Chapter 1 Introduction to the Study	1
1.1 Background to the study	1
1.2 Problem statement and aim of the study.....	3
1.3 Brief summary of the methodology of the study	4
1.3.1 Research design and phases	4
1.3.2 Participant selection	4
1.3.3 Materials and methods	5
1.3.4 Data collection.....	6
1.3.5 Data analysis.....	6
1.4 Ethical considerations	6
1.4.1 Confidentiality.....	7
1.5 Significance of the study	7
1.6 Limitations of the study	8
1.7 Layout of the dissertation.....	8
1.8 Appendices	9
Chapter 2 Literature Review	11
2.1 Inflammatory bowel disease	11
2.2 Incidence and prevalence of inflammatory bowel disease	12
2.2.1 Inflammatory bowel disease in sub-Saharan Africa and South Africa	12
2.3 Impact of inflammatory bowel disease	13
2.4 Diagnosis of inflammatory bowel disease	14

2.4.1	Laboratory test/biochemical assessment for inflammatory bowel disease	14
2.4.2	Imaging tests for inflammatory bowel disease.....	15
2.4.3	Magnetic resonance enterography and computed tomography	30
2.5	Conclusion	31
Chapter 3 Study Design, Materials and Methods.....		32
3.1	Introduction.....	32
3.2	Study location	33
3.3	Study population and sampling method	33
3.4	Study design	34
3.5	Materials and methods.....	35
3.5.1	Phase 1: Designing the research instrument.....	36
3.5.2	Phase 2: Producing a preliminary diagnosis of inflammatory bowel disease with bowel ultrasound	37
3.5.3	Phase 3: Comparing the preliminary and confirmatory diagnosis of inflammatory bowel disease.....	42
3.5.4	Phase 4: Analysing data	42
3.6	Validity and reliability of the data	45
3.6.1	Validity	45
3.6.2	Reliability.....	45
Chapter 4 Preliminary and Confirmatory Diagnosis of Inflammatory Bowel Disease		47
4.1	Introduction	47
4.2	Biographical information of the sample population	47
4.3	Preliminary diagnosis of inflammatory bowel disease using the bowel ultrasound parameters .	49
4.3.1	Presentation of bowel ultrasound parameter measurements	49
4.3.2	Preliminary inflammatory bowel disease ultrasound diagnosis using the eight bowel ultrasound parameter measurements	53
4.4	Confirmation of preliminary diagnoses of inflammatory bowel disease.....	58
4.5	Comparison of the preliminary diagnosis and confirmation of inflammatory bowel disease.....	62
4.5.1	Accuracy estimates	62
4.5.2	Independence tests.....	63

4.6 Potential uses of ultrasound for diagnosing inflammatory bowel disease	72
Chapter 5 Discussion and Conclusion	73
5.1 Introduction	73
5.2 Role of ultrasound in diagnosis of inflammatory bowel disease	74
5.3 Conclusion	75
References	76
Appendices	93

List of Tables

Table 3.1	Inclusion and exclusion criteria of the study	34
Table 3.2	Description of potential BUS parameters of the research instrument for the potential diagnoses of IBD	37
Table 4.1	Descriptions of measurements found for the different potential BUS parameters	50
Table 4.2	Preliminary IBD ultrasound diagnosis (yellow shaded blocks) according to the BUS parameters (green shaded blocks).....	55
Table 4.3	Number of patients for whom ancillary intra-abdominal pathologies were identified during the ultrasound scan	57
Table 4.4	Presence of IBD ultrasound diagnoses versus confirmed diagnosis of IBD	59
Table 4.5	Numbers and percentages of positive and negative BUS parameter diagnoses for IBD	62
Table 4.6	Accuracy estimates of all BUS parameters as diagnostic measures for IBD.....	63
Table 4.7	Contingency table for bowel wall thickness comparing patient numbers for preliminary IBD diagnosis and confirmed IBD diagnosis	64
Table 4.8	Contingency table for vascularity, comparing patient numbers for preliminary IBD diagnosis and confirmed IBD diagnosis	65
Table 4.9	Contingency table for bowel wall stratification comparing patient numbers for preliminary IBD diagnosis and confirmed IBD diagnosis	66
Table 4.10	Contingency table for haustration, comparing patient numbers for preliminary IBD diagnosis and confirmed IBD diagnosis	67
Table 4.11	Contingency table for fatty wrapping comparing patient numbers for preliminary IBD diagnosis and confirmed IBD diagnosis	68
Table 4.12	Contingency table for peristalsis comparing patient numbers for preliminary IBD diagnosis and confirmed IBD diagnosis	69
Table 4.13	Contingency table for mesenteric lymph nodes comparing patient numbers for preliminary IBD diagnosis and confirmed IBD diagnosis	70
Table 4.14	Contingency table for free fluid comparing patient numbers for preliminary IBD diagnosis and confirmed IBD diagnosis	71
Table 4.15	Contingency table for diagnostic procedure, comparing patient numbers for preliminary IBD diagnosis and confirmed IBD diagnosis	72

List of Figures

Figure 2.1	Diagram of inflammatory bowel disease.....	12
Figure 2.2	Diagram of sono-anatomy of the normal bowel wall.....	19
Figure 2.3	Bowel wall thickness parameter. A: Diagram of bowel wall layers; B: BUS image of bowel wall thickness stretching from the lumen–mucosa interface to the muscularis propria–serosal interface.....	20
Figure 2.4	BUS image of bowel wall stratification	21
Figure 2.5	BUS image of fatty wrapping and inflammatory lymph nodes. A: Fatty wrapping around an inflamed bowel (arrows); B: Inflammatory (reactive) lymph nodes (*)	22
Figure 2.6	LIMBERG scoring system showing Scores 0 to 4	24
Figure 2.7	Complications of small bowel Crohn's disease. A: Stenosis with pre-stenotic dilatation (arrow: stenosis, asterisk: pre-stenotic dilatation); B: Retroperitoneal fistula arrows: fistula); C: Abscess (arrow)	27
Figure 2.8	Toxic megacolon of a thin-walled and dilated transverse colon	28
Figure 2.9	Primary sclerosing cholangitis with inflammatory thickening of the intrahepatic bile ducts, causing bright echogenic portal triads (arrowhead)	29
Figure 3.1	Flow diagram of the data-capturing and analysis steps.....	44
Figure 4.1	Percentages of participating patients in different age intervals	48
Figure 4.2	Number of participating patients representing different ethnic groups.....	49
Figure 4.3	BUS images showing examples of presentations of potential BUS parameters used for the diagnosis of suspected IBD.	52
Figure 4.4	Number of participating patients showing suspected IBD using the potential BUS parameters and number of patients diagnosed negative for IBD	54
Figure 4.5	Comparison of the number of patients diagnosed with or without inflammatory bowel disease in preliminary and confirmatory diagnoses.....	58

Abbreviations

BUS:	Bowel ultrasound
CTE:	Computed tomography enterography
ECCO:	European Crohn's and Colitis Organization
EFSUMB:	European Federation of Societies for Ultrasound in Medicine and Biology
ESGAR:	European Society of Gastrointestinal Radiology
HOD:	Head of department
HSREC:	Health Sciences Research Ethics Committee
IBD:	Inflammatory bowel disease
ID:	Identity
MEDITECH:	Medical Information Technology
MRE:	Magnetic resonance enterography
PACS:	Picture Archiving and Communication System

List of Definitions

Bowel ultrasound: A safe, non-invasive diagnostic test that uses low and high-frequency transducers, sound waves and a computer to visualise the bowel or to produce images of the bowel/internal body parts (Andrzejewska & Grzymislowski, 2018).

Colonoscopy: A diagnostic and therapeutic procedure that is used to evaluate the large intestine and the distal portion of the small intestine (terminal ileum). A colonoscopy is performed with a handheld, flexible, tube-like device called a colonoscope, which helps to detect abnormalities and overgrowth of the colonic wall and allows a biopsy to be taken (Stauffer & Pfeifer, 2024).

Biopsy: The removal of tissue from any part of the body to examine it for disease (Hoffman, 2022).

Crohn's disease: A chronic disease that causes inflammation in the digestive tract. Crohn's disease can affect any part of the digestive tract, which runs from the mouth to the anus, but usually affects the small intestine and the start of the large intestine (Roda et al., 2020).

Ulcerative colitis: A chronic inflammatory disorder that causes mucosal inflammation of the colon (Higuera, 2020).

Longitudinal/sagittal plane: An anatomical plane that divides the body into right and left parts (Smith, 2013).

Transverse plane: Also called an axial plane, it is an imaginary plane that divides the body into superior and inferior parts (Smith, 2013).

Cranial/coronal plane: A vertical plane running from side to side, which divides the body into anterior and posterior parts (Smith, 2013).

Transducer: A device that produces sound waves that bounce off body tissues and produce echoes. The transducer receives the echoes and transmits them to a computer that uses them to create a picture/image (LBNMEDICAL, 2022).

Limberg scoring system: A widely accepted semi-quantitative color Doppler ultrasound assessment of the bowel wall vascularity in inflammatory bowel disease (Botz, 2021; Rimola et al., 2022).

Pneumoperitoneum: The presence of air or gas in the abdominal (peritoneal) cavity (Khan, 2021).

Abstract

Introduction: Inflammatory bowel disease (IBD) is a chronic disease characterised by a chronic relapsing–remitting pattern that causes chronic inflammation in the gastrointestinal tract. This pattern causes long-term bowel damage and complications, such as stenosis and perforation, which affect the patient’s quality of life. Early diagnosis is, therefore, crucial, to ensure effective management of this disease. The diagnostic and monitoring gold standard is a colonoscopic examination with a biopsy. This procedure is invasive and carries the risk of bowel perforation. Therefore, a non-invasive alternative, such as a bowel ultrasound (BUS) examination is advantageous. Therefore, the aim of this study was to determine the accuracy of a BUS examination in the diagnosis of IBD when compared to the gold standard colonoscopy with biopsy.

Main research question: What is the accuracy of BUS as a diagnostic imaging modality for the diagnosis of IBD, compared to colonoscopy with biopsy?

Methods: The research question was addressed by undertaking a stepwise process to determine the ultrasound accuracy compared to the confirmed (histology) diagnosis (through colonoscopy and biopsy) in patients with IBD. The study population was 77 adult patients with suspected clinical symptoms of IBD, or patients diagnosed with IBD. All participating patients underwent a clinical and biochemical assessment, endoscopic procedures (colonoscopy with biopsy), and an abdominal ultrasound scan of the bowel, which was performed by a single sonographer. Eight ultrasound parameters for IBD were gleaned from the literature and used to perform the BUS examination. The accuracy of BUS for detecting IBD was determined by comparing the BUS diagnosis with the confirmatory diagnosis obtained from the biopsy histological reports. The Fisher’s exact test was performed to determine if a statistically significant association existed between the two variables – the BUS IBD diagnosis and the confirmatory IBD diagnosis – using histological examination at a significance level of 0.05. Fisher’s exact tests were also performed individually on each BUS

parameter to determine if a statistically significant association existed between the different diagnostic patient groups.

Results: The BUS diagnosis of IBD was accurate in more than 80% of the participating patients in the population. The accuracy estimates of the BUS parameters for the diagnosis of IBD were greater than 80% for bowel wall thickness and vascularity, while the estimates for the other parameters ranged from 66% to 72%. The Fisher's exact test established a significant association between the BUS diagnosis and the confirmatory diagnosis of IBD (two-tailed $p < 0.00001$).

Significance: A BUS is a non-invasive, accurate imaging tool that can be included in the diagnostic workup approach for the primary or first-line examination of IBD. A BUS is a safe, inexpensive procedure that can be used as a screening tool for rapid diagnosis of IBD patients.

Keywords: Bowel ultrasound; inflammatory bowel disease; colonoscopy; ulcerative colitis; Crohn's disease; bowel ultrasound parameters; histology; bowel biopsy

Chapter 1

Introduction to the Study

1.1 Background to the study

Inflammatory bowel disease (IBD) is a chronic disorder that causes chronic inflammation in the gastrointestinal tract. It is an autoimmune disease in which the immune system of the body attacks parts of the digestive system (Furfaro et al., 2021). This disease has a chronic relapsing-remitting pattern, which causes long-term bowel damage and complications, such as stenosis and perforation (Furfaro et al., 2021). Worldwide, IBD is showing an increase in incidence and prevalence, and it is recognised today as a global disease of the twenty-first century (Hodges & Kelly, 2020). IBD may occur at any stage of life and affects men and women equally. It is more common in the White population and in people with a family history of IBD (Maconi et al., 2018).

Inflammatory bowel disease affects both the small and large bowel. The most common types of IBD are Crohn's disease and ulcerative colitis (Nassef et al., 2014). Crohn's disease is a chronic IBD that causes inflammation in the lining of the digestive tract and can develop in any part of the digestive system (Zhang & Li, 2014). Ulcerative colitis, on the other hand, causes chronic inflammation, mainly in the colon and the rectum (Zhang & Li, 2014; Gros & Kaplan, 2023).

Various clinical symptoms characterise IBD; these symptoms come and go and may also affect other parts of the body. The clinical symptoms of IBD may vary, depending on which part of the bowel is affected and the severity of the disease (Walfish & Ching-Companiononi, 2023). Patients with IBD usually present with clinical symptoms such as abdominal pain, bloody stools, fatigue, diarrhoea, weight loss, iron deficiency and other features of malabsorption (Sanders & Winter, 2007; Muradali & Goldberg, 2015; Perler et al., 2019). To diagnose and confirm the disease, patients with

clinical symptoms of IBD should undergo clinical and biochemical assessment, endoscopic procedures (colonoscopy with biopsy), and various diagnostic imaging procedures. Early detection and management of IBD are crucial, as this may limit the risk of complications, which affects the patient's quality of life (Novak et al., 2015).

Diagnostic imaging plays a vital role in diagnosing and monitoring patients with suspected IBD, both at the time of diagnosis and throughout the course of the disease. Diagnostic imaging procedures are performed to determine the location, extension, activity and severity of the disease and to exclude or confirm any disease complications (Panes et al., 2013). Diagnostic imaging procedures that are used to diagnose and monitor IBD patients include colonoscopy with a biopsy, magnetic resonance imaging, computed tomography and bowel ultrasound (BUS). Today, a colonoscopy with a biopsy is the gold standard for diagnosing IBD (Fodor et al., 2021). However, a colonoscopy cannot evaluate the entire bowel or assess IBD complications, such as abscesses, strictures and fistulas (Bots et al., 2018). Colonoscopy is also expensive and invasive and carries the risk of bowel perforation, which emphasises the importance of a non-invasive and safe imaging tool for diagnosing and monitoring IBD (Hajiani et al., 2018). Colonoscopy with biopsy for histology is performed for confirmation, and other imaging modalities augment the IBD diagnosis.

A BUS is a diagnostic imaging modality that yields similar information by looking at different parameters. A BUS is a safe, non-invasive, inexpensive, fast reproducible and widely available imaging tool with high sensitivity (up to 85%) and specificity (95%) to diagnose and assess IBD (Kucharzik et al., 2017; Allocca, Fiorino, Bonifacio et al., 2018). The European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) established and recommends standardised ultrasound guidelines for assessing patients with IBD. These ultrasound guidelines include standardised ultrasound techniques and parameters/scoring systems for when cross-sectional imaging modalities such as BUS, computed tomography and magnetic resonance imaging

are used (Macconi et al., 2018; Maaser et al., 2019). According to the EFSUMB guidelines, BUS may be used as an alternative to colonoscopy for detecting relapse or monitoring treatment response during follow-up visits (Jauregui-Amezaga & Rimola, 2021). Research studies also suggest that BUS can be the primary or first-line imaging tool to detect and monitor IBD (Stroebe et al., 2011; Jauregui-Amezaga & Rimola, 2021). The European Crohn's and Colitis Organisation (ECCO) and European Society of Gastrointestinal Radiology (ESGAR) recommended that BUS is used to detect IBD at its first presentation, and to diagnose its complications (Macconi et al. 2018, Maaser et al., 2022). In most countries, BUS is currently accepted as the first line of investigation for diagnosing and monitoring IBD (Stroebe et al., 2011; Jauregui-Amezaga & Rimola, 2021).

1.2 Problem statement and aim of the study

The study was conducted in the radiology department at a public hospital in Bloemfontein in the Free State, South Africa, which also serves private-hospital patients. In this hospital, the current approach is that all patients with suspected IBD routinely undergo BUS scans (cross-sectional imaging) and repeated colonoscopies and biopsies to confirm the presence or absence of IBD and to monitor treatment response. As the researcher, I was employed as an ultrasonographer in this hospital when it came to my attention that most of the patients who underwent BUS and invasive colonoscopies had not always been diagnosed with IBD. Subjecting a patient to both procedures (BUS and colonoscopy) resulted in relatively high medical costs and added to a patient's trauma because of the invasive nature of colonoscopy. A BUS is recommended to detect IBD at its first presentation and serves as an alternative diagnostic test to colonoscopy for detecting relapse or for monitoring treatment response (Macconi et al., 2018; Jauregui-Amezaga & Rimola, 2021; Maaser et al., 2022); however, the comparative accuracy of BUS and colonoscopy has not yet been definitely confirmed. Therefore, the aim of the study was to ascertain the accuracy of BUS compared to a colonoscopy with biopsy for diagnosing IBD. Therefore, the research question that was addressed in this study is:

What is the accuracy of BUS as a diagnostic imaging modality for the diagnosis of IBD compared to colonoscopy with biopsy?

To achieve the aim of this study, the following objectives were pursued:

- 1) To design a research instrument to guide the data-capturing process;
- 2) To generate the final BUS report that confirms IBD (preliminary diagnosis);
- 3) To evaluate the accuracy of each potential BUS parameter using histology as the gold standard; and
- 4) To ascertain the accuracy of BUS for detecting IBD using histology as the gold standard.

1.3 Brief summary of the methodology of the study

1.3.1 Research design and phases

This was a prospective descriptive study that used quantitative data. The study was conducted over four phases in a stepwise process to achieve the aim of the study. An abdominal ultrasound scan, which included the bowel, was prospectively performed on participating patients with clinical symptoms of IBD. The first phase of the study involved designing the research instrument that guided the data-capturing process, using potential BUS parameters for IBD. The second phase of the study involved generating the preliminary diagnosis and, in the third phase, the preliminary ultrasound diagnosis was compared with the confirmed (histology) diagnosis (through colonoscopy and biopsy) to determine the accuracy of BUS for detecting IBD. The fourth phase of the study was the data analysis phase.

1.3.2 Participant selection

Probability sampling was used to select participants. The sample size was calculated using an online sample size calculator; the recommended sample size was 77. Adult patients from the public

hospital and the private hospital who attended the gastroenterology clinic and the Clinical Imaging Sciences Department from December 2022 to August 2023 and who had clinical symptoms of IBD were invited to participate in the study.

1.3.3 Materials and methods

Participating patients underwent clinical and biochemical assessments, endoscopic procedures (colonoscopy with biopsy) and abdominal ultrasound scan of the bowel. After obtaining local ethics approval and written informed consent from each participating patient, the pilot study was conducted on the first 10 patients who met the inclusion criteria.

One sonographer performed a complete transabdominal ultrasound scan, including the bowel, which took 20–25 minutes. A standardised technique was applied, with high-resolution ultrasound and color Doppler as recommended by the EFSUMB guidelines for IBD (Atkinson et al., 2017). A research instrument (ultrasound checklist) that includes all the recommended standardised ultrasound parameters for IBD was used to confirm or exclude evidence of IBD during the abdominal/bowel ultrasound scan. The ultrasound findings were recorded and saved on PACS (Picture Archiving and Communication System); it was interpreted and confirmed by a consultant radiologist who generated the final ultrasound report (preliminary diagnosis). The preliminary diagnosis was compared with each participating patient's confirmed (histology) diagnosis to establish the accuracy by which BUS could detect IBD.

The study excluded:

- 1) All patients under the age of 18 years;
- 2) All patients with severe abdominal tenderness or unstable heart conditions or who were acutely ill;
- 3) All participants who declined or withdrew their consent to participate in the study; and
- 4) Pregnant patients.

1.3.4 Data collection

Data were collected from the ultrasound checklist, the final BUS report (preliminary diagnosis), and the histology and colonoscopy reports (confirmed diagnosis). The final ultrasound reports were retrieved from PACS, and the histology and colonoscopy reports were retrieved from MEDITECH (Medical Information Technology) or collected from the participating patients' hospital files, which were stored at the gastroenterology clinic. After all the data had been collected, the final BUS results (preliminary diagnosis) were compared with the histology/confirmed diagnosis to determine the accuracy of BUS for detecting IBD.

1.3.5 Data analysis

The data from the final ultrasound reports, the histology and colonoscopy reports, and the baseline data were captured electronically in Microsoft Excel. Further statistical analysis was performed using SAS Version 9.2. Descriptive statistics, including nominal frequencies and percentages, were calculated for the categorical data and means or medians and percentiles were calculated for the numerical data. The Shapiro-Wilk test was used to investigate whether numerical data followed a normal distribution. To compare the accuracy of BUS for diagnosing IBD compared to colonoscopy with a biopsy, Fisher's exact test was performed to accommodate groups of less than five and to determine the independence of groups at a significance level (α) of 0.05.

1.4 Ethical considerations

Ethics approval to conduct the study was obtained from the Health Sciences Research Ethics Committee (HSREC) (Appendix A), the Free State Department of Health (Appendix B), and the Ethics Research Committee of the private hospital (Appendix C). Permission to conduct the study at the public hospital was obtained from the head of department (HOD) of the gastroenterology clinic (Appendix D), the HOD of Clinical Imaging Sciences (Appendix E), and the gastroenterologists

managing the patients diagnosed with IBD at the private hospital (Appendix F). Written informed consent (Appendix G) was obtained from each participating patient before the ultrasound scan.

1.4.1 Confidentiality

All study information was confidential and only used for research purposes. Measures were taken to safeguard the identity and anonymity of participating patients. Records of participants, except informed consent, did not contain identification data of the participating patients, to ensure that it cannot be traced back to the participating patient. Anonymising the participating patients' data ensured that collected patient data could not be linked to a specific individual. All participating patients received a random ID (identity) number. The link between a participant's name and the ID number was destroyed immediately after the study by the researcher. No data were recorded that could identify the participating patient. The de-identified data were saved in a research data repository. The researcher created a folder to save all the data on a personal password-protected laptop, encrypted the file, and applied password protection with different passwords. A copy of the data was stored in a locked cabinet in the HOD's office. Names of participating patients will not be used in journal articles or at meetings when the results of this study will be reported. The anonymity of all participants, as stated above, complies with the Protection of Personal Information Act (POPIA). The research was conducted per the prescriptions, recommendations and requirements of the Declaration of Helsinki (World Medical Association, 2013).

1.5 Significance of the study

The study may contribute to promoting the use of a safe, non-invasive, accurate and relatively inexpensive diagnostic imaging tool that can be used repeatedly in the diagnostic workup of IBD patients at this hospital in Bloemfontein. It may be that BUS is the non-invasive diagnostic imaging modality of choice for the gastroenterologist, and it may be used as an alternative to invasive

colonoscopy with biopsy. A BUS may also be used as an accurate screening tool for patients with suspected IBD. Using standardised ultrasound parameters for IBD may assist in image interpretation and ensure an accurate diagnosis. The research instrument used in this study may be helpful as a potential training tool for ultrasound operators at the research site in the future.

1.6 Limitations of the study

Several limitations were experienced while conducting this study. The sample size of the study was relatively small and limited to one public academic hospital that also serves private patients. A larger study might clarify the diagnostic accuracy of BUS as a diagnostic tool. The ultrasound image quality was compromised by obesity, bowel gas, faecal material, pneumoperitoneum and patients whose abdomens were very tender. If bowel gas was present, it was technically difficult to assess the rectum optimally with ultrasound. Accessing the colonoscopy and histology results of the participating patients was a challenge, as not all these results had been captured on MEDITECH. Patients who were booked for a colonoscopy did not all report for their appointments as expected, which resulted in the study taking slightly longer to achieve the planned sample size.

1.7 Layout of the dissertation

This thesis is arranged in five chapters, with the following content:

Chapter 1: Introduction to the study

The field of study was introduced, the research problem was identified, and the aim, objectives, significance and limitations of the study, as well as a brief summary of the methodology of the study, were included.

Chapter 2: Literature review

Current literature on IBD will be reviewed. Topics such as the impact of the disease on the population, diagnosis of the disease and the role of BUS, colonoscopy, and other imaging modalities will be described.

Chapter 3: Materials and methods

This chapter will describe how the study was conducted to answer the research question. It will describe the methods and materials/equipment used to select participants and how data were collected and analysed. The application of research ethics principles will be explained.

Chapter 4: Results

In this chapter, the main findings of the data collection and statistical analysis will be presented concisely and objectively. This chapter will explain the type of statistical analysis that was used to obtain the results.

Chapter 5: Conclusion and recommendations

This chapter will provide a summary of the study, reiterate the problem and aim of the study, and explain what was done to solve the problem. It will give an overview of the results and their implications, summarise the study benefits and limitations and make recommendations for future studies.

1.8 Appendices

Appendix A: Approval letter from HSREC

Appendix B: Approval letter from Free State Department of Health

Appendix C: Approval letter from the Research Ethics Committee of the private hospital

Appendix D: Permission letter from the HOD (Gastroenterology) to conduct the study

Appendix E: Permission letter from HOD (radiology department) to conduct the study

Appendix F: Permission letter from the gastroenterologists of the private hospital to conduct the study

Appendix G: Informed consent form

Appendix H: Letter from the statistician

Appendix I: Letter from the language editor

Appendix J: Turnitin report

Chapter 2

Literature Review

2.1 Inflammatory bowel disease

The chronic condition of IBD causes chronic inflammation in the gastrointestinal tract. This chronic disease is characterised by a chronic relapsing-remitting pattern, which causes long-term bowel damage and complications, such as stenosis and perforation (Wilson, 2020; Furfaro et al., 2021; Windsor et al., 2023). The exact cause of IBD is still unknown, though it is believed that IBD may result from a weakened immune system, a disruption of the immune system, genetics, an autoimmune condition, and environmental factors (Furfaro et al., 2021; Tavakoli et al., 2021; Saoji et al., 2024). The condition of IBD can occur at any stage of life and involves either the small or the large bowel (Maconi et al., 2018). Crohn's disease and ulcerative colitis are the two most common types of IBD (Nassef et al., 2014; Tavakoli et al., 2021; Saoji et al., 2024; Figure 2.1).

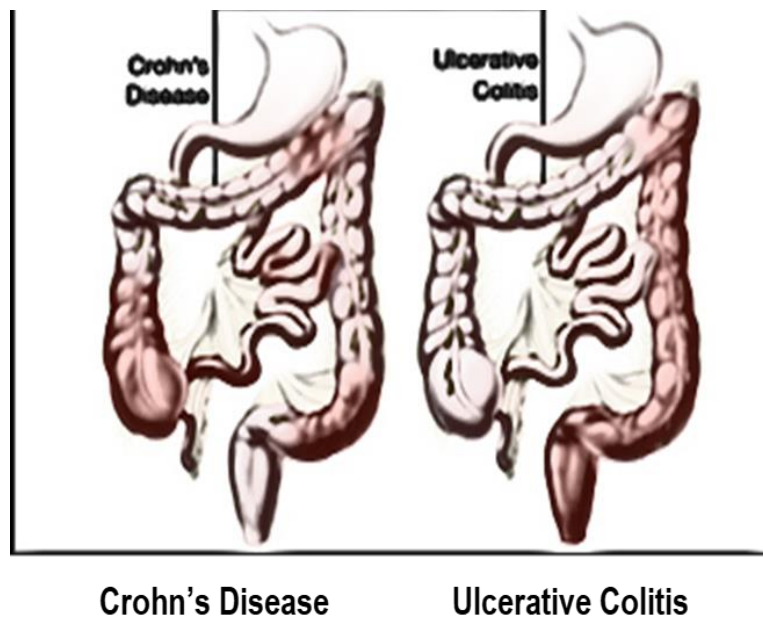


Figure 2.1 Diagram of inflammatory bowel disease (Glasgow Colorectal Centre, s.a.)

2.2 Incidence and prevalence of inflammatory bowel disease

In the twenty-first century, IBD has emerged as a global disease with an increasing prevalence worldwide, especially in newly industrialised countries, such as Eastern Europe and Asia. The incidence of IBD has increased significantly over the last decades and affects over 6 million people worldwide (Watermeyer et al., 2020; Silangcruz et al., 2021). It is estimated that more than one million adults suffer from IBD in the United States of America (Silangcruz et al., 2021). The highest incidence of IBD is in North America and Europe (Watermeyer et al., 2020; Ashton & Beattie, 2023). The incidence of IBD in sub-Saharan Africa is also rising (Hodges & Kelly, 2020).

2.2.1 Inflammatory bowel disease in sub-Saharan Africa and South Africa

Although IBD is recognised as a global disease of the twenty-first century, very little is known about its epidemiology in sub-Saharan Africa. Hodges and Kelly (2020) state that this lack of epidemiological data might be due to the many challenges relating to IBD that face the healthcare

systems in sub-Saharan Africa. These challenges include inadequate access to diagnostic facilities (endoscopy and histopathology facilities), underreporting of IBD cases, financial challenges related to medical treatment for patients with IBD, and the difficulty of differentiating between the diagnoses of Crohn's disease and intestinal tuberculosis (Hodges & Kelly, 2020; Watermeyer et al., 2023).

However, research has found that IBD is not uncommon in South Africa. IBD is a well-recognised disease in the White population, though it is relatively rare in indigenous African populations (Chonco et al., 2021). Ulcerative colitis was found to be the most frequent type of IBD; in turn, Crohn's disease commonly occurs with disease complications and is mostly found in populations with mixed ancestry/mixed race (Basson et al., 2014; Hodges & Kelly, 2020; Watermeyer et al., 2020).

2.3 Impact of inflammatory bowel disease

A global increase in the prevalence of IBD can cause a major financial burden for patients diagnosed with IBD, the healthcare systems, communities and a country's economy. It has become clear that IBD is an incurable disease that has major effects on different aspects related to the quality of life of patients who have the disease, as well as on family members or caretakers of these patients (Mitropoulou et al., 2022; Watermeyer et al., 2023). Patients who have IBD may recover after a single attack of the disease and remain in remission for years, while others may require frequent hospitalisations and surgery. The unpredictable nature of the disease affects a patient's quality of life through ongoing symptoms, such as reduced ability to work, social stigma, struggles with bathroom access, difficulty with physical intimacy and restrictions on career choices (Silangcruz et al., 2021). Patients diagnosed with IBD require lifelong medical treatment and continuous monitoring of the bowel to detect complications of the disease and initiate treatment response (Novak et al., 2015; St-Pierre et al., 2023; Saoji et al., 2024). Without proper treatment or early diagnosis of IBD, symptoms can worsen considerably and complications, such as abscesses, obstruction, malnutrition and

anaemia, are common (Fakhoury et al., 2014). Patients with long-term ulcerative colitis are at increased risk of requiring a colectomy and developing colorectal cancer (Gros & Kaplan, 2023).

2.4 Diagnosis of inflammatory bowel disease

Early diagnosis of IBD is crucial for patients with the clinical symptoms of the disease. Early diagnosis is vital for disease management, as it might speed up treatment and limit the risk of complications developing. Diagnosing IBD may often require repetitive, invasive, expensive, time-consuming and poorly tolerated diagnostic tests (Ślósarz et al., 2021). To diagnose and confirm IBD, a gastroenterologist relies on a combination of clinical symptoms, laboratory tests, diagnostic imaging tests and histological examination of tissue specimens to establish the diagnosis and determine the extent and severity of the disease.

2.4.1 Laboratory test/biochemical assessment for inflammatory bowel disease

Serum biomarkers have become essential in IBD diagnosis because they are non-invasive, convenient and relatively inexpensive compared to markers in biopsy tissue, stool and other body fluids. C-reactive protein and faecal calprotectin are the two main inflammatory marker tests currently used to detect bowel inflammation. C-reactive protein is a test that measures the level of C-reactive protein in the blood. An elevated C-reactive protein level in the blood indicates the presence of inflammation in the body (Wilkens et al., 2022). C-reactive protein is the most widely used inflammatory marker and has shown a strong correlation with Crohn's disease activity, while it has a lower correlation with ulcerative colitis (Chen et al., 2020; Wilkens et al., 2022). In turn, faecal calprotectin is a non-invasive test that measures the calprotectin level in a patient's stool. Faecal calprotectin is more specific than C-reactive protein for bowel inflammation and is routinely used to monitor disease activity and treatment response (Nardone et al., 2022). An elevated calprotectin level may indicate the presence of IBD. A study done by Ho et al. (2021) found that faecal

calprotectin provided a sensitivity of 96.6% and a specificity of 52.3% in diagnosing IBD in children. Faecal calprotectin is a useful screening test for distinguishing inflammatory from noninflammatory gastrointestinal conditions, such as irritable bowel syndrome (Ho et al., 2021).

Limitations of C-reactive protein and faecal calprotectin markers

C-reactive protein can sometimes be falsely negative and is not disease-specific to IBD. Elevated C-reactive protein levels also occur with non-IBD enteritis, inflammatory disorders unrelated to the gastrointestinal tract, tissue damage, diabetes, malignancies and cardiovascular disease (Chen et al., 2020). A normal C-reactive protein level can also be found in patients with active IBD and in asymptomatic IBD patients with mild mucosal lesions (Chen et al., 2020). Faecal calprotectin has a lower accuracy rate for detecting small-bowel inflammation (Novak et al., 2016). Elevated faecal calprotectin levels are, furthermore, not specific to IBD (Ho et al., 2021; Saoji et al., 2024).

2.4.2 Imaging tests for inflammatory bowel disease

Diagnostic imaging tests have become the core feature of the holistic approach needed to diagnose and manage patients with IBD. The primary purpose of diagnostic imaging is to detect the disease early, to identify the presence and severity of the disease, to evaluate the response to the treatment, and to detect extra-intestinal complications. The diagnostic imaging tests that are used for this purpose include endoscopy (colonoscopy with a biopsy), BUS, magnetic resonance enterography (MRE) and computed tomography enterography (CTE).

Colonoscopy with a biopsy

A colonoscopy is a medical test that enables the gastroenterologist to examine the intestinal lining for inflammation, ulcers and other signs of IBD. Today, colonoscopy with a biopsy is the gold standard for diagnosing IBD (Novak et al., 2017; Matsuoka et al., 2018; Fodor et al., 2021; Rimola et al., 2022). Combining colonoscopy with a biopsy is not only used to diagnose IBD, but also helps to

monitor treatment response and to differentiate between Crohn's disease and ulcerative colitis (Spiceland & Lodhia, 2018). Colonoscopy and a biopsy are also used to exclude other non-IBD-related conditions with similar clinical presentations (Spiceland & Lodhia, 2018; Ashton & Beattie, 2023). Several colonoscopic validated activity scores have been used to assess disease activity in patients with IBD (Bots et al., 2018).

Limitations of colonoscopy

Colonoscopy is an expensive and invasive procedure that carries the risk of bowel perforation, which emphasises the importance of a non-invasive and safe imaging modality to diagnose and monitor IBD. A colonoscopy cannot evaluate the entire bowel or assess complications of IBD and is not appropriate for frequent and repetitive reassessments of disease activity (Bots et al., 2018; Alfarone et al., 2022). Colonoscopy is contraindicated for patients with severe colitis and toxic megacolon and is not very well accepted by IBD patients (Spiceland & Lodhia, 2018; Rimola et al., 2022). A colonoscopy procedure requires bowel preparation and can be uncomfortable for patients.

Cross-sectional imaging for IBD

Cross-sectional imaging, including BUS, MRE and CTE, plays a vital role in the diagnosis and management of IBD. Cross-sectional imaging techniques are better tolerated and safer than colonoscopy and have been used for years as a complementary tool to colonoscopy for assessing patients for IBD (Rimola et al., 2022). These techniques enable efficient and non-invasive visualisation of the bowel lumen, wall and extra-intestinal manifestations of the disease (Starakiewicz & Grand, 2013; Rimola et al., 2022). Cross-sectional imaging techniques are accurate, reliable tools for assessing IBD activity and can detect features of IBD that are not even visible in colonoscopy (Alfarone et al., 2022; Rimola et al., 2022). The EFSUMB has established a standardised approach to assessing patients for IBD using cross-sectional imaging. This

standardised approach enables a more uniform understanding of disease activity when reporting and interpreting IBD images, to ensure accurate diagnosis (Shaban et al., 2022).

Bowel ultrasound

A BUS is a safe, non-invasive, inexpensive, fast and reproducible imaging test. Studies have found that BUS is widely available and produces a highly accurate, sensitive and specific response for diagnosing and monitoring IBD (Kucharzik et al., 2017; Alloca, Fiorino, Bonovas et al., 2018; Andrzejewska & Grzymislawski, 2018; Alshammari et al., 2021). Significant improvements in technology and ultrasound equipment and the growing expertise of ultrasound operators have increased the role of ultrasound, as a non-invasive imaging modality, in detecting and monitoring IBD. The European Crohn's and Colitis Organisation and the European Society of Gastrointestinal and Abdominal Radiology (ECCO-ESGAR) guidelines recommend using BUS to assess disease activity and complications in Crohn's disease (Maaser et al., 2022). Ultrasound is well accepted and tolerated by patients, and it can easily evaluate the entire bowel segment, compared to colonoscopy, which is currently the gold standard (Jauregui-Amezaga & Rimola, 2021). In most developed countries, BUS is currently accepted as a first-line or primary method of investigation for diagnosing and monitoring IBD (Stroebe et al., 2011; Calabrese et al., 2012; Jauregui-Amezaga & Rimola, 2021). A BUS is useful for diagnosing IBD, primarily by evaluating the bowel wall thickness, wall stratification and surrounding structures (Wilkins et al., 2016; Kamel et al., 2020). Compared to other imaging modalities, BUS has the same level of accuracy as colonoscopy and MRE in assessing and monitoring IBD (Allocca et al., 2020). A BUS has the same level of accuracy in detecting IBD complications as MRE and CTE (Hate & Imamura, 2022). Compared to other non-invasive diagnostic tools, such as faecal calprotectin, BUS offers additional information on the disease extension, location, severity and complications (Frias-Gomesa et al., 2021). Ultrasound is a helpful tool for guiding abscess drainage resulting from IBD. BUS can offer direct visualisation of the colon

segments and ileum, which makes assessing the bowel wall layers easier (Parente et al., 2002). However, to interpret BUS correctly, it is important to have a firm knowledge and understanding of the normal bowel anatomy, the fundamentals of physical principles of ultrasound imaging, and ultrasound techniques, which may assist in the interpretation of abnormal BUS findings (Atkinson et al., 2017). The normal bowel wall is stratified and shows of five sonographic layers when it is examined with ultrasound (Kuzmich et al., 2009; Boccacatonda et al., 2023). Figure 2.2 illustrates these layers:

The hyperechoic mucosal layer is the interface between the mucosa and the bowel lumen.

The hypoechoic/muscularis mucosa layer represents the packed glandular tissue; its thickness varies.

The hyperechoic submucosa layer contains connective tissue with vessels, nerves and fat.

The hypoechoic muscularis propria layer has an inner circular and an outer longitudinal muscular layer.

The hyperechoic serosa layer is the visceral peritoneum.

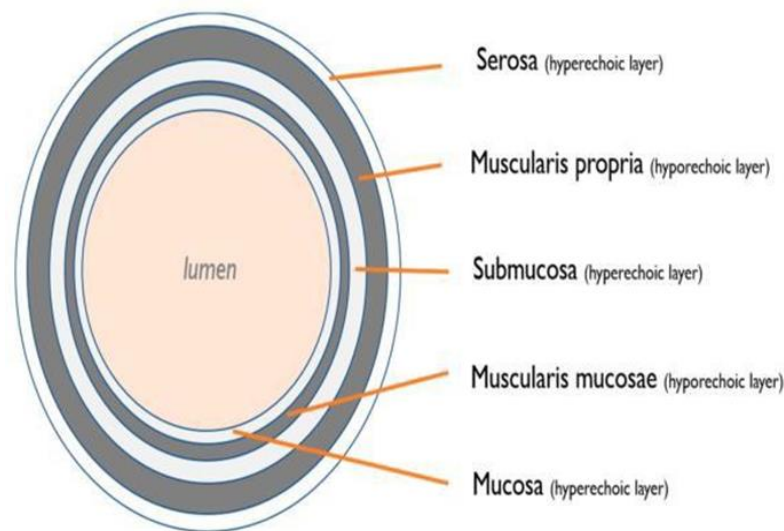


Figure 2.2 Diagram of sono-anatomy of the normal bowel wall (Jauregui-Amezaga & Rimola, 2021)

The EFSUMB established standardised ultrasound guidelines for diagnosing and assessing patients with IBD. These guidelines include standardised techniques and parameters/scoring systems for use with cross-sectional imaging modalities such as BUS. The guidelines recommend that BUS is used to determine disease activity and as a complementary imaging tool to detect IBD (Maconi et al., 2018; Maaser et al., 2019; Jauregui-Amezaga & Rimola, 2021). The EFSUMB identified various standardised ultrasound parameters/features for IBD that characterise bowel inflammation, which is easily identified with grayscale ultrasound and color Doppler and that may help in the diagnosis of IBD. The standardised BUS parameters are bowel wall thickness, bowel wall stratification, haustration, fatty wrapping, lymph nodes, peristalsis, free fluid and vascularity.

Bowel wall thickness

Bowel wall thickness is the distance measured from the lumen–mucosa interface to the muscularis propria–serosal interface (Dell’Era et al., 2023; Dolinger & Kayal, 2023). This measurement is done in the longitudinal plane in the anterior wall and by avoiding haustrations and mucosal folds

(Figure 2.3). Bowel wall thickness is the only fully quantitative parameter, the most reliable parameter and the most commonly used ultrasound parameter for diagnosing IBD (Magro et al., 2017; Nardone et al., 2022). As recommended by the EFSUMB guidelines, a bowel wall thickness of > 3 mm is considered abnormal (Kucharzik & Maaser, 2018; Maconi et al., 2018; Wilkens et al., 2022).

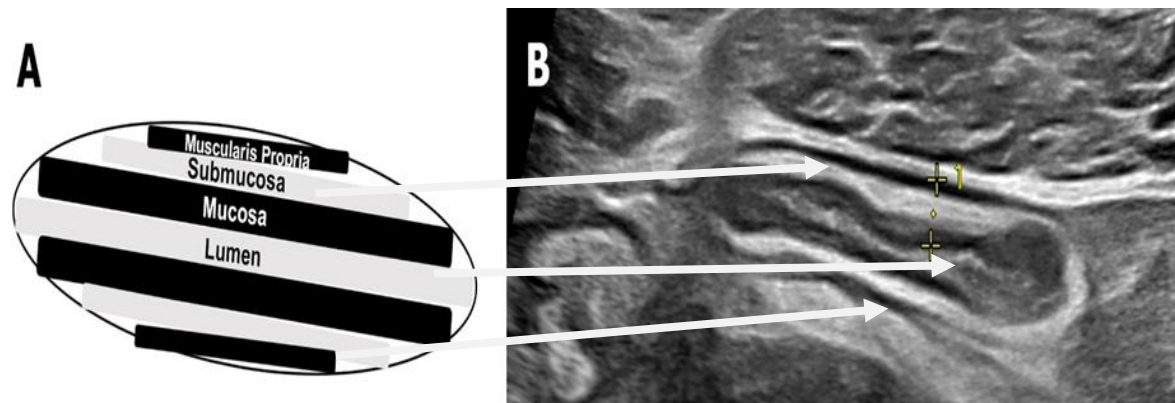


Figure 2.3 Bowel wall thickness parameter. A: Diagram of bowel wall layers; B: BUS image of bowel wall thickness stretching from the lumen–mucosa interface to the muscularis propria–serosal interface (Dolinger & Kayal, 2023)

Bowel wall stratification

As mentioned, the normal bowel wall is stratified (it has a clearly defined multilayered aspect); however, inflammation can disrupt this stratification, either focally or extensively. Disruption of stratification is associated with higher degrees of inflammation. A thickened bowel wall with loss of stratification suggests an increased risk for surgery in patients with Crohn's disease (Maconi et al., 2018; Figure 2.4).

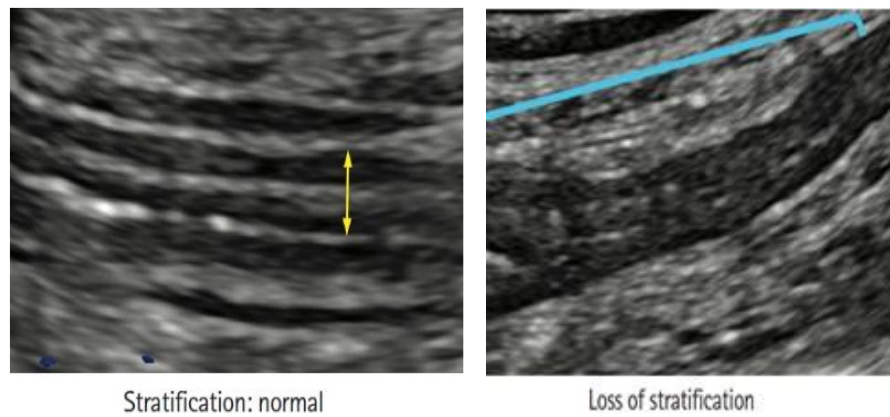


Figure 2.4 BUS image of bowel wall stratification (Miyoshi et al., 2023)

Haustration

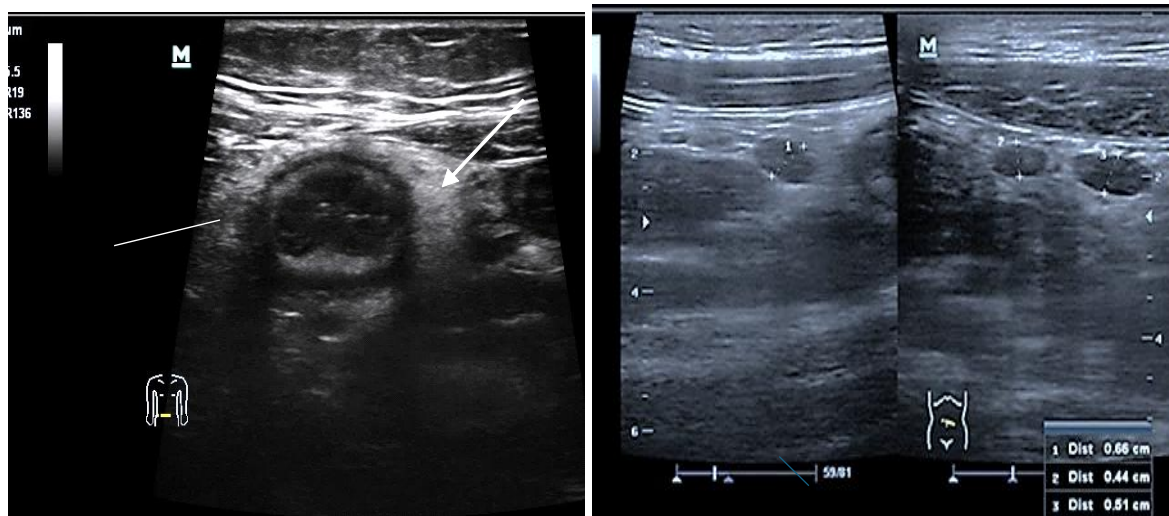
Loss of haustration in the colonic bowel segments, that is, loss of small pouches of the colon as a result of sacculation, may occur in the case of severe or longstanding inflammation (De Voogd et al., 2021; Wilkens et al., 2022).

Fatty wrapping (increased inflammatory mesenteric fat)

What appears to be hyperechoic, almost solid tissue surrounding the inflamed bowel is mainly seen in patients with longstanding Crohn's disease (Figure 2.5A; Jauregui-Amezaga & Rimola, 2021).

Lymph nodes

The presence of enlarged inflammatory (reactive) mesenteric lymph nodes is not specific to IBD but can be found with noninflammatory bowel pathology. Mesenteric lymph nodes related to Crohn's disease are small, oval-shaped hypoechoic structures less than 5 mm in diameter. This finding is less specific than bowel wall thickness, bowel wall stratification and vascularity for predicting disease activity (Figure 2.5B; Furfaro et al., 2021).



A - Fatty wrapping

B -Lymph nodes

Figure 2.5 BUS image of fatty wrapping and inflammatory lymph nodes. A: Fatty wrapping around an inflamed bowel (arrows); B: Inflammatory (reactive) lymph nodes (Furfaro et al., 2021)

Peristalsis

The presence of peristalsis helps differentiate between the colon and small bowel. A BUS can evaluate peristalsis and the compressibility of the bowel. A lack of compressibility and peristalsis is seen in cases of wall stiffness (Jauregui-Amezaga & Rimola, 2021).

Free fluid

Free fluid is a common reproducible BUS finding that is seen close to the inflamed bowel loop. This finding is nonspecific because it is commonly seen in several non-IBD conditions (Maconi et al., 2018).

Vascularity

The Limberg scoring system, which is a semi-quantitative color Doppler ultrasound method, is used to assess the vascularity of the bowel wall in IBD (Kucharzik & Maaser, 2018; Rimola et al., 2022; Di Muzio et al., 2024). Vascularity on color Doppler imaging will be considered when coloured pixels are consistently reproduced at the same location (Nassef et al., 2014). The color or power Doppler ultrasound measures vascularity at the thickened bowel wall segments. An increased vascularity within a thickened bowel wall may indicate disease activity (Sturm et al., 2019; Wilkens et al., 2022; Boccata et al., 2023). The Limberg scoring system ranges from Grade 0 to Grade 4 (Figure 2.6).

Grade 0: Normal bowel wall with no thickening, well-delineated mural stratification, and no mural flow (no color Doppler signal)

Grade 1: A thickened hypoechoic bowel wall without vascular signals

Grade 2: A hypoechoic thickened bowel wall with short stretches of vascularity

Grade 3: Hypoechoic bowel thickening with longer stretches of vascularity

Grade 4: Vascular signals are seen in the bowel wall and extending into the surrounding mesentery (Limberg & Osswald, 1994; Kucharzik & Maaser, 2018; Miyoshi et al., 2023; Di Muzio et al., 2024)

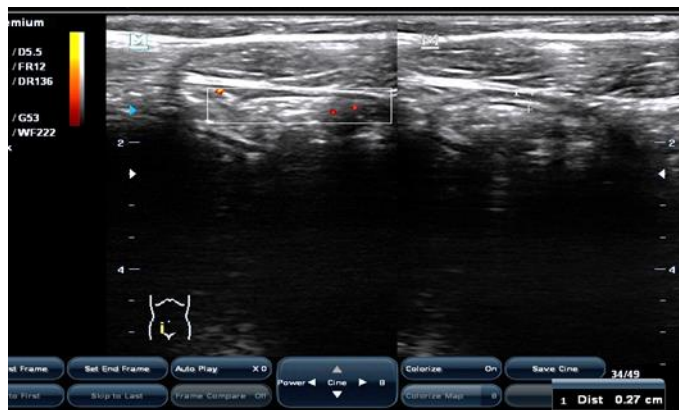
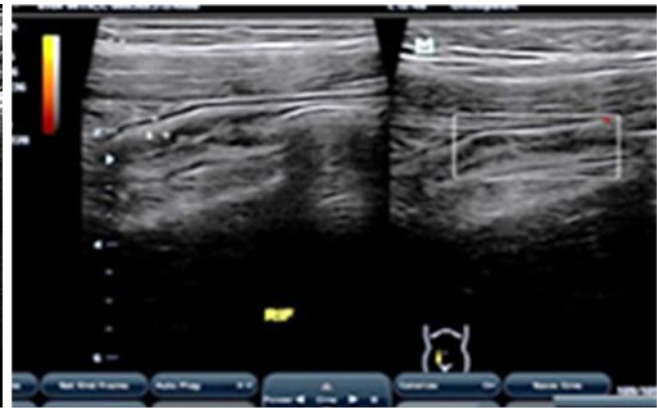
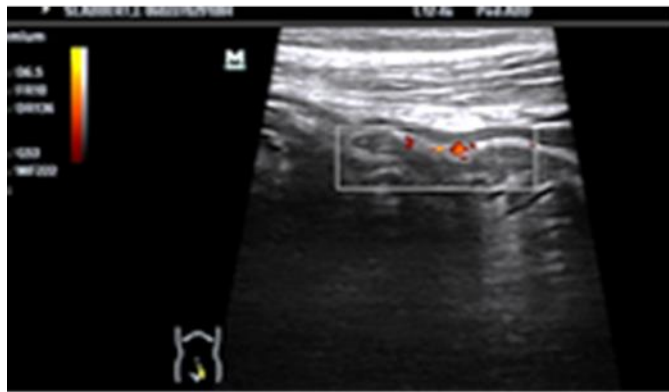
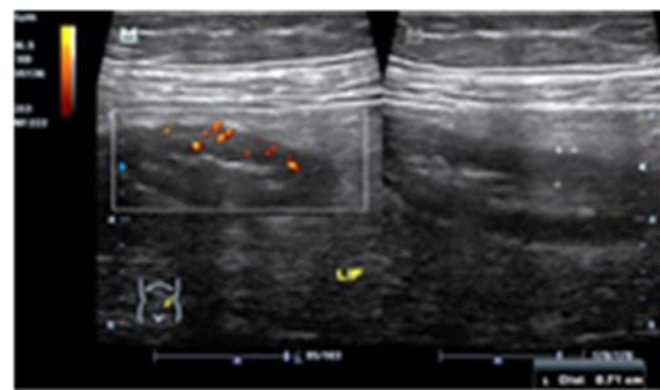
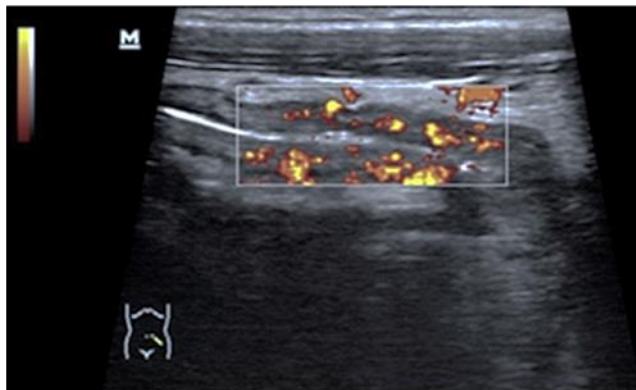
**Grade 0****Grade 1****Grade 2****Grade 3****Grade 4**

Figure 2.6 LIMBERG scoring system showing Grade 0 to 4: Grade 0 represents a normal bowel wall with no thickening, well-delineated mural stratification, and no mural flow (no color Doppler signal); Grade 1 represents a thickened hypoechoic bowel wall without vascular signals; Grade 2 represents a hypoechoic thickened bowel wall with short stretches of vascularity; Grade 3

represents a hypoechoic bowel thickening with longer stretches of vascularity and Grade 4 represents vascular signals seen in the bowel wall and extending into the surrounding mesentery (Limberg & Osswald, 1994; Kucharzik & Maaser, 2018; Miyoshi et al., 2023; Di Muzio et al., 2024)

Complications of inflammatory bowel disease on ultrasound

For some patients, IBD may be a mild illness; for others, it may be a debilitating condition that can lead to life-threatening complications. IBD complications can occur with Crohn's disease and ulcerative colitis. Studies have found that BUS accurately detects Crohn's disease and ulcerative colitis complications with a sensitivity as high as 100% (Novak, 2016; Wilkens et al., 2022). Crohn's disease and ulcerative colitis have common complications and others that are specific to each condition. Complications of IBD, which are common in both Crohn's disease and ulcerative colitis, include colon cancer, skin, eye and joint inflammation, side effects of the IBD medication and blood clots; IBD complications that are specific to each condition are discussed in the next subsections.

Complications of Crohn's disease

Strictures are characterised by bowel wall thickening, with a narrowed (less than 10 mm) lumen with prestenotic dilatation (Figure 2.7a; Wilkens et al., 2022). Recent studies have found that a BUS is a highly accurate technique for detecting strictures (Wilkens et al., 2022). Strictures are characterised by different degrees of inflammation and fibrosis. Inflammatory strictures will appear hypoechoic and highly vascular, and fibrotic ones will demonstrate a normal stratified echo pattern with no or poor vascularity (Jauregui-Amezaga & Rimola, 2021). It is important to differentiate between the two because patients with fibrotic stenosis need surgery, and those with inflamed stenosis will benefit from medical treatment (Jauregui-Amezaga & Rimola, 2021). However, BUS is

not very accurate for determining the degree of inflammation or fibrosis of a stricture (Jauregui-Amezaga & Rimola, 2021).

Fistulas are seen on ultrasound as a hyperechoic tract with a diameter less than 2 cm, with or without internal gaseous artifacts originating from the bowel wall, either with a blind end or in continuity with mesenteric structures and confining organs (Figure 2.7b). The sensitivity of BUS for detecting fistulising disease is about 67–87% (Furfaro et al., 2021; Wilkens et al., 2022).

Abscesses are seen as hypo-anechoic structures that contain fluid and gaseous artefacts and have posterior enhancement and irregular margins, sometimes within hypertrophic mesentery, without vascular signals at color Doppler (Figure 2.7c). An inflammatory mass will be seen as an irregular hypoechoic structure with vascular signals on color Doppler (Furfaro et al., 2021).

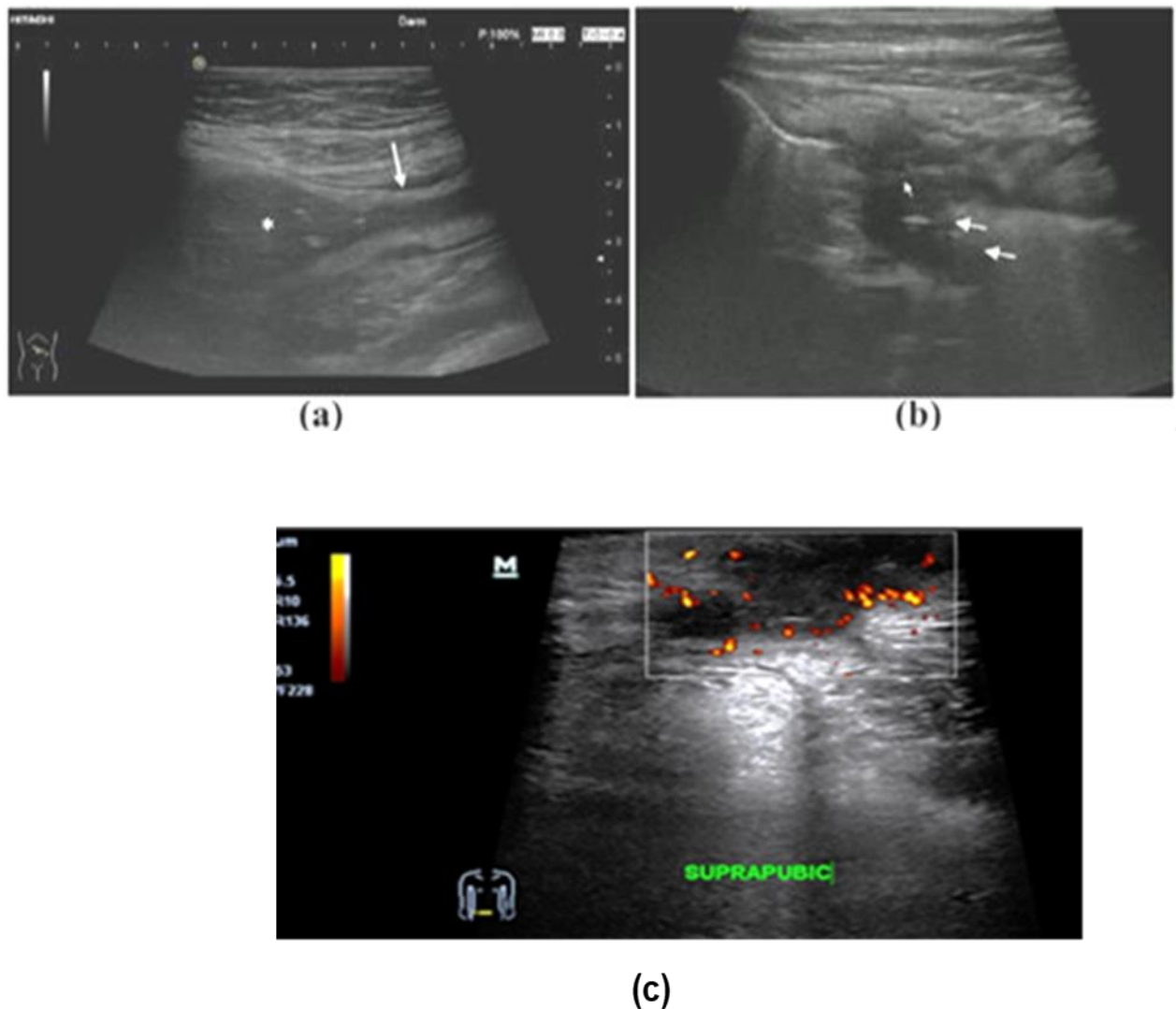


Figure 2.7 Complications of small bowel Crohn's disease. A: Stenosis with pre-stenotic dilatation (arrow: stenosis, asterisk: pre-stenotic dilatation); B: Retroperitoneal fistula (arrows: fistula); C: Abscess with increased vascular signals on color Doppler (Arrows) (Kucharzik & Maaser, 2018)

Complications of ulcerative colitis

BUS can detect extra-intestinal complications of ulcerative colitis, such as toxic megacolon and primary sclerosing cholangitis (Maconi et al., 2018). Toxic megacolon and bowel perforation are the most frightening complications of ulcerative colitis. Ulcerative colitis may cause the colon to widen

rapidly and swell (abnormal dilation > 6 cm), thereby causing a toxic megacolon. Toxic megacolon can be total or segmental (Maconi et al., 2018; Skomorochow & Pico, 2020). Ultrasound findings of toxic megacolon may include loss of haustra coli of the colon, hypoechoic and thickened bowel walls with irregular internal margins in the sigmoid and descending colon, dilation of the transverse colon (> 6 cm) and dilation of ileal bowel loops with increased intraluminal gas and fluid (Hate & Imamura, 2022; Figure 2.8).

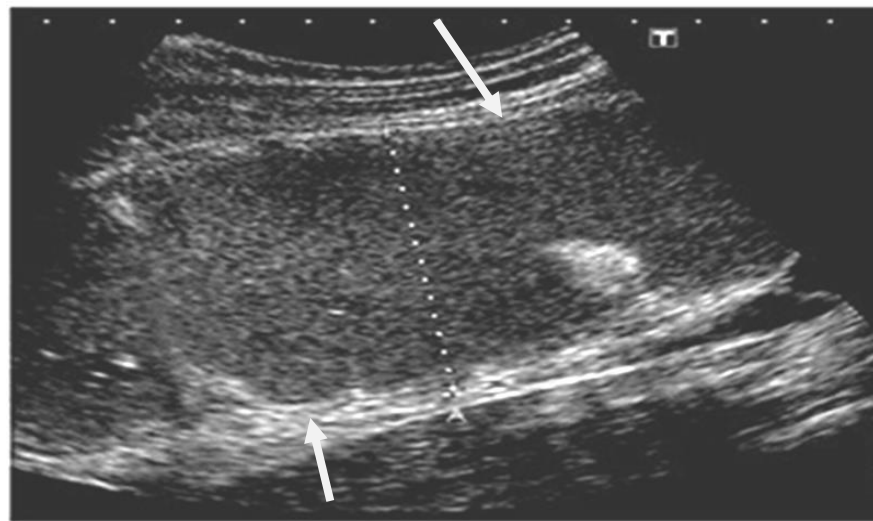


Figure 2.8 Toxic megacolon of a thin-walled and dilated transverse colon (arrows)
(Uchino et al., 2015)

Some patients with ulcerative colitis may also develop primary sclerosing cholangitis. Primary sclerosing cholangitis results from chronic inflammation that causes scarring in the bile ducts, which narrows the bile ducts and leads to restricted bile flow, which eventually causes liver damage (Van Munster et al., 2024). Ultrasound findings for primary sclerosing cholangitis may include wall thickening of the central intrahepatic or extrahepatic bile duct, echogenic portal triads, or areas of segmental biliary duct dilation (Morgan et al., 2022; Figure 2.9).

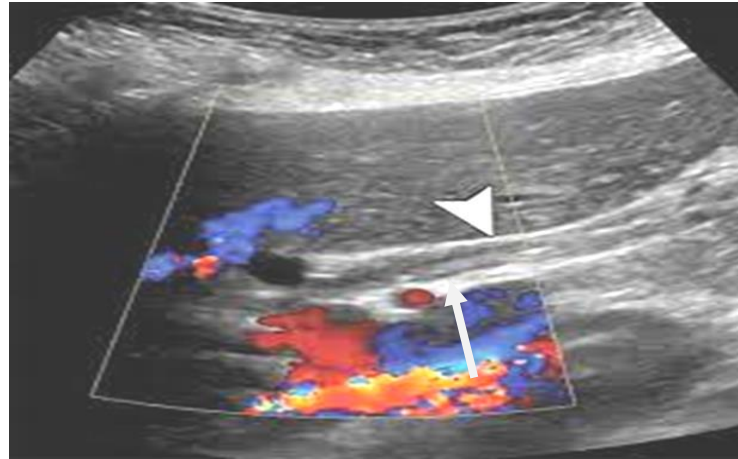


Figure 2.9 Primary sclerosing cholangitis with inflammatory thickening of the intrahepatic bile duct (arrows) (Khoshpouri et al., 2019)

Advanced bowel ultrasound techniques

In addition to B-mode imaging, advanced ultrasound techniques that may increase the accuracy of BUS are contrast-enhanced ultrasonography and shear wave elastography. Contrast-enhanced ultrasound and shear wave elastography combined enable better characterisation of the degree of fibrosis and inflammation of bowel strictures, which is very important in patients with Crohn's disease (Thimm et al., 2019). Contrast-enhanced ultrasound is most useful for determining the degree of acute inflammation and is not as valuable for assessing bowel wall fibrosis (Grażyńska et al., 2021). In turn, shear wave elastography can identify bowel wall fibrosis by evaluating tissue stiffness (Lu et al., 2017; Thimm et al., 2019; Rimola et al., 2022). Shear wave elastography has also been found to be less operator-dependent and reproducible (Rimola et al., 2022). Contrast-enhanced ultrasound is used to evaluate the small bowel and to determine postoperative recurrence (Rimola et al., 2022).

Limitations of bowel ultrasound

BUS is operator-dependent, which may affect the accuracy and reliability of the technique as an imaging modality. The image quality of ultrasound can be compromised by obesity, bowel gas,

faecal material and pneumoperitoneum and if a patient has a very tender abdomen. It is difficult to assess the rectum optimally with ultrasound. A study performed by Hajiani et al. (2018) found that ultrasound is not an accurate imaging tool for assessing patients with ulcerative colitis, because of the location of the disease and the patient's body mass index (Hajiani et al., 2018). Rimola et al. (2022) state that contrast ultrasound techniques may improve BUS, but the technique is not yet standardised for IBD. Contrast-enhanced ultrasound is expensive and not widely used.

2.4.3 Magnetic resonance enterography and computed tomography

Both MRE and CTE are important in evaluating small-bowel disorders. Both MRE and CTE are highly accurate in detecting small-bowel disease extension and complications of Crohn's disease (Alfarone et al., 2022). Both MRE and CTE allow simultaneous cross-sectional evaluation of the entire bowel, making it easy to look for the complications of IBD, such as small-bowel obstruction, abscesses or fistulae (Starakiewicz & Grand, 2013; Fakhoury et al., 2014). Magnetic resonance and computed tomography can effectively differentiate between active inflammation and fibrosis and monitor the effectiveness of treatment, which is important, especially for patients with Crohn's disease (Starakiewicz & Grand, 2013; Alfarone et al., 2022). CTE is often preferred for older patients and patients presenting with acute symptoms because of its low cost, ease of interpretation and greater availability than MRE (Alfarone et al., 2022). Because MRE does not expose patients to ionising radiation, it is preferred for young patients. According to Shaban et al. (2022), MRE has been used as the gold-standard cross-sectional imaging technique for monitoring luminal small-bowel Crohn's disease and is a more accurate imaging tool for aiding in initial disease mapping (Shaban et al., 2022). Because MRE can effectively assess the entire bowel as well as the anus and can detect small perianal fistulae that are too difficult to see on CTE, MRE is often used for patients with suspected perianal disease (Starakiewicz & Grand, 2013. Alfarone et al., 2022).

Limitations of MRE and CTE

Both CTE and MRE diagnostic imaging tests are costly. In CTE, the risk of overexposure to radiation for the patient increases cancer risk (Davari et al., 2019; Alfarone et al., 2022). Compared to CTE, MRE examinations take longer, and have more artifacts associated with peristalsis and bowel gases (Novak et al., 2016; Alfarone et al., 2022). Access to MRE facilities is limited and more expensive. (Novak et al., 2016; Alfarone et al., 2022). Inadequate clinical expertise could influence the interpretation of MRE and CTE images and the accuracy of IBD diagnoses (Muradali & Goldberg, 2015).

2.5 Conclusion

The global increase in the prevalence and incidence of IBD and the significant impact this incurable disease has on the quality of life of patients with IBD, as well as the financial burden on the healthcare systems and economy, emphasises the importance of early diagnosis and treatment. Diagnosing IBD with a diagnostic tool that is accurate, widely available (in a point-of-care setting), non-invasive, inexpensive and easy to repeat may be of great value in the diagnostic workup of IBD patients. A BUS is an imaging tool that gives immediate results that may help in the decision-making process for IBD treatment and management of the disease. A colonoscopy with a biopsy remains the gold standard for diagnosing IBD (Rimola et al., 2022). Research reports good accuracy between MRE and colonoscopy for the diagnosis of IBD (Rimola et al., 2022). However, the accuracy of BUS compared to the gold standard, colonoscopy with a biopsy, is not well known. The aim of this study was to ascertain the accuracy of BUS compared to colonoscopy with a biopsy for detecting or diagnosing IBD.



Chapter 3

Study Design, Materials and Methods

3.1 Introduction

The usefulness of BUS, which uses non-invasive ultrasound parameters to detect IBD, is internationally recognised and it is used as an accurate imaging tool for diagnostic workups of patients with suspected IBD. At the research site, diagnosis of patients with suspected IBD is performed with colonoscopy and biopsy (the gold standard), as well as a BUS (cross-sectional imaging), which is a costly approach. Colonoscopy and biopsy are also invasive and poorly tolerated by patients. BUS has been recommended as the imaging modality of choice, as an alternative diagnostic test or first-line of investigation for patients with IBD; however, the comparative accuracy of BUS and colonoscopy is not yet well known (Alloca, Fiorino, Bonovas et al., 2018; Jauregui-Amezaga & Rimola, 2021). Thus, this study was undertaken to ascertain the accuracy of BUS compared to the gold standard, colonoscopy with biopsy, for diagnosing IBD. Therefore, the research question that was addressed in this study is:

What is the accuracy of BUS as a diagnostic imaging modality in the diagnosis of IBD compared to colonoscopy with biopsy?

To answer this research question, the following objectives were devised:

- 1) To design a research instrument to guide the data-capturing process;
- 2) To generate the final BUS report that confirms IBD (preliminary diagnosis);
- 3) To evaluate the accuracy of each potential BUS parameter using histology as the gold standard; and
- 4) To ascertain the accuracy of BUS for detecting IBD using histology as the gold standard.

3.2 Study location

The study was conducted in the Clinical Imaging Sciences Department (Radiology) at a public academic hospital that also provides medical services to private patients in Bloemfontein, in the Free State province of South Africa. These patients had been referred to the department by gastroenterologists of the gastroenterology clinic at the public hospital and a gastroenterologist at a private hospital in Bloemfontein. This hospital was selected for this study because it is a tertiary academic hospital that provides specialised healthcare services to patients of secondary hospitals and one private hospital in the Free State and Northern Cape provinces. Patients are served 24 hours a day by consultant radiologists, registrar radiologists, gastroenterologists and other specialists and who are equipped with state-of-the-art medical and ultrasound equipment. The Clinical Imaging Sciences Department at this hospital provides diagnostic imaging and interventional procedures, including ultrasound, bone densitometry scans, MRI scans, computed tomography scans, fluoroscopy, X-rays and mammography. At the time of the study, this hospital was the only public hospital in Bloemfontein that performed colonoscopies.

3.3 Study population and sampling method

The sampling method of a research study refers to the way a sample population is selected from the target population (Elfil & Negida, 2017). There are two basic sampling methods: probability and non-probability sampling. In probability sampling, every participant is equally likely to be included in the research study. In non-probability sampling, not every participant is likely to be included (McCombes, 2019; 2023b).

A probability sampling method was used to select participants for this study. Furthermore, proportional random sampling was used, as the sample of participants was proportional to the total number of the IBD population who visited the gastroenterology clinic and the Clinical Imaging



Sciences Department between December 2022 and August 2023. To estimate the required sample size for this study, the number of patients ($n = 96$) who had undergone colonoscopy with biopsy for IBD during the same period in the previous year was used to calculate the minimum sample size with an online sample size calculator. This calculation was made at a confidence interval of 95% and a margin of error of 5% (Kibuacha, 2021). This calculation revealed that 77 participating patients was the minimum requirement for this study.

Adult patients with suspected IBD who visited the gastroenterology clinic and the Clinical Imaging Sciences Department from December 2022 to August 2023 were invited to participate in the study. Willing patients provided written consent. After applying the inclusion and exclusion criteria, the patients who agreed to the study underwent BUS (Table 3.1).

Table 3.1 Inclusion and exclusion criteria of the study

Inclusion criteria	Exclusion criteria
Patients older than 18 years	Patients younger than 18 years
Patients with diagnosed IBD or presenting with clinical symptoms suggesting IBD, including abdominal pain, weight loss, bleeding per rectum, chronic diarrhoea and iron deficiency	Clinically unstable patients, such as patients with severely tender abdomens or unstable heart conditions
Patients had to be scheduled for a colonoscopy and biopsy or have had a recent colonoscopy and biopsy at the time of the abdominal ultrasound referral	Pregnant patients
	All patients who declined to participate or withdrew from participating during the study

3.4 Study design

This prospective descriptive study was undertaken to ascertain the accuracy of BUS to diagnose IBD. A descriptive study design was chosen for this study to describe a population and the situation in conditions under which the data were collected (McCombes, 2023a). Quantitative data were



collected to describe the characteristics of the population (Siedlecki, 2020). The quantitative data were subjected to statistical analyses of the numerical data (Bhandari, 2023; McCombes & George, 2023).

The study was conducted in four phases in a stepwise process. The first phase of the study was to design the research instrument to guide the data-capturing process using potential BUS parameters for IBD. The second phase involved generating the preliminary diagnosis of IBD. An abdominal ultrasound scan was performed by using the research instrument as a guide to collect the data to generate the final ultrasound report (preliminary diagnosis). In the third phase, the preliminary diagnosis was compared to the confirmed diagnosis (through the colonoscopy and biopsy) to determine the accuracy of BUS in detecting IBD. The fourth phase of the study involved an analysis of the data.

3.5 Materials and methods

Ethics approval to conduct the research study was obtained from the HSREC of the University of the Free State in Bloemfontein, South Africa. To obtain this approval, a research protocol with applicable documentation was submitted to HSREC (Appendix A). After the HSREC granted conditional approval, permission was also obtained from the Free State Department of Health (Appendix B) and the private hospital (Appendix C). Permission to conduct the study at a public academic hospital in Bloemfontein was obtained from the HOD of the gastroenterology clinic (Appendix D), from the HOD of Clinical Imaging Sciences (Appendix E), and the gastroenterologists who managed patients diagnosed with IBD at the private hospital (Appendix F). Once all the relevant permission letters had been obtained, the HSREC granted final ethics approval. Because ultrasound is a safe, non-invasive, radiation-free imaging procedure, it was not necessary to obtain permission from the Radiation Control Committee for this study.

Written informed consent was obtained from each participant before the examination. Each participating patient received a consent form with an information document explaining the purpose/aim, objectives and overall goal of the study. The informed consent form and information document were available in English, Afrikaans and Sesotho (Appendix G). In addition, participating patients were sensitised to the following:

- 1) Participation in this study was entirely voluntary. Participants had the right to refuse to participate in the study, and even if they had agreed to participate in the study, they could withdraw from the study at any time.
- 2) Participants were not charged for participating in this study, nor did they receive any remuneration for participation.
- 3) Participants who were willing to participate in the study received consent forms to sign. The researcher discussed the content of the consent form before participants were required to sign it.

After obtaining all the relevant ethics approvals, the study was executed in four phases.

3.5.1 Phase 1: Designing the research instrument

A research instrument was designed to guide the preliminary diagnosis of IBD with a BUS scan. A literature review was undertaken to identify potential BUS parameters that could be used for the diagnosis of IBD. A checklist was constructed comprising two sections. The first section made provision for biographical information of participating patients. In the second section of the checklist, the potential parameters were listed with reference values or instructions for diagnosing the presence or absence of IBD.

From the literature, eight parameters were considered relevant to this study. These BUS parameters are bowel wall thickness, vascularity (identified using color Doppler signals), bowel wall stratification,

haustration of the colon, fatty wrapping, peristalsis, mesenteric lymph nodes, and free fluid.

Table 3.2 provides a list of the potential BUS parameters and descriptions of measurement criteria for IBD used by this study.

Table 3.2 Description of potential BUS parameters of the research instrument for the potential diagnoses of IBD

Potential BUS parameter	Measurement criteria for potential IBD	Source
Bowel wall thickness	Bowel wall thickness of more than 3 mm	Maconi et al. (2018) Kucharzik and Maaser (2018)
Vascularity	Increased vascularity within the thickened bowel wall was measured using color Doppler signal (ultrasound)	Maconi et al. (2018) Nassef et al. (2014)
Bowel wall stratification	Presence of focal or extensive disruption of bowel wall layers	Maconi et al. (2018)
Haustration	Loss of haustration of the colonic bowel segment, which means loss of the small pouches of the colon caused by sacculation	De Voogd et al. (2021)
Fatty wrapping	Presence of hyperechoic, almost solid tissue surrounding the inflamed bowel segment	Jauregui-Amezaga and Rimola (2021)
Peristalsis	Lack of compressibility and lack of peristalsis	Jauregui-Amezaga and Rimola (2021)
Mesenteric lymph nodes	Presence of hypoechoic oval-shaped solid structures (reactive lymph nodes)	Furfaro et al. (2021) Maconi et al. (2018)
Free fluid	Presence of free fluid close to the inflamed bowel segment	Maconi et al. (2018)

3.5.2 Phase 2: Producing a preliminary diagnosis of inflammatory bowel disease with bowel ultrasound

A pilot study was undertaken to validate the ultrasound checklist. This pilot study was performed with the first 10 participating patients, to determine whether the checklist required amendments. The pilot

study revealed that the checklist required no further changes and could be used to capture the ultrasound data for the main study; the data of the 10 patients were therefore included in the main study. After the checklist had been validated, it was applied to the other patients participating in the study. The researcher, who worked at the hospital as a sonographer and who had more than 15 years of experience in the modality, completed the checklist for each participating patient during the BUS scan. Each participating patient was given a random ID number. The BUS scan was performed using a standardised technique with high-resolution ultrasound and color Doppler imaging, as recommended by the EFSUMB guidelines for IBD (Atkinson et al., 2017), to assess the sigmoid colon, descending colon, transverse colon, ascending colon, terminal ileum, proximal small bowel and rectum. The scans were performed using a Toshiba Aplio 500 Platinum (Toshiba, Tokyo, Japan) ultrasound machine and a range of transducers, including using a 5-17 MHz high-frequency linear array transducer for superficial bowel wall resolution and a 3-5 MHz low-frequency convex transducer to evaluate deep structures and to exclude any complications of IBD or any other gross intra-abdominal pathology.

Each BUS scan took approximately 25 minutes and was performed in the following manner:

- 1) Before participants were scanned, they were prepared for the ultrasound scan. First, they were instructed to fast for at least 6 hours before the ultrasound scan. Some participants were given water to drink just before the examination was performed to improve bowel peristalsis and visualisation of the small bowel.
- 2) The ultrasound checklist (research tool) was used to confirm or exclude evidence of IBD during the abdominal/BUS scan by identifying the presence or absence of the eight BUS parameters using the following scanning technique:
 - a) The abdominal ultrasound scan was performed with the patient in a relaxed, supine position. Gel was applied on the patient's skin as a coupling medium to replace the

air between the patient's skin and the transducer, as ultrasound cannot travel through air (Afzal et al., 2022). The whole intestine (the sigmoid colon, descending colon, transverse colon, ascending colon, terminal ileum, proximal small bowel and rectum) and abdominal organs were examined using conventional greyscale ultrasound and color Doppler ultrasound.

- b) The low frequency convex transducer was used, first, for an overall abdominal assessment to identify any gross intra-abdominal pathology. The sonographer assessed the liver, spleen, pancreas, gallbladder, kidneys and urinary bladder, and the ultrasound findings of these organs or any complications of IBD were recorded. All structures were assessed in the longitudinal and transverse planes.
- c) The examination continued with the high frequency transducer to thoroughly assess the bowel segments, the bowel wall, and other intra-abdominal superficial structures. The bowel segments were assessed, starting at the right anterior superior iliac crest; the transducer was moved medially to the edge of the rectus muscles in a longitudinal plane until the common iliac vessels were identified. The transducer was then rotated anticlockwise into a transverse plane and moved cranially until the first bowel segment, the terminal ileum, was visualised crossing from medial to lateral. With the transducer still in the transverse plane, the bowel segment was followed to the ileocecal valve and the cecum, where the appendix was identified, and the bowel segment was followed upwards to the hepatic flexure and the transverse colon. To evaluate the transverse colon, the transducer was moved and placed in the epigastric region in a longitudinal plane, and the gastrocolic ligament was followed to the transverse colon. The transducer was moved from side to side and up and down to evaluate the transverse colon. The rest

of the colon was followed distally towards the rectum and thoroughly examined for large bowel abnormalities.

- d) In cases where it was difficult to identify the terminal ileum, the same technique was followed on the left side, where the sigmoid colon was identified as the first bowel loop crossing the left iliac vessels, and was followed to the descending colon upwards to the spleen, splenic flexure, and to the transverse colon and then followed downwards to the right iliac fossa to the cecum. To improve the visualisation of the splenic flexure, an intercostal approach was used, and the participant was positioned in a semi-decubitus position, with the left arm elevated to spread the ribs for optimal evaluation.
- e) To assess the small bowel, the transducer was again placed in the right iliac fossa to identify the terminal ileum; the terminal ileum was followed in a proximal direction to get an overview of the jejunal and ileal segments. The transducer was swept up and down the abdomen to evaluate the small bowel for abnormalities. The bowel segments were assessed in the longitudinal and transverse planes.
- f) Bowel wall thickness was measured in the most affected intestinal segments, on the anterior wall, and in the longitudinal plane, by avoiding haustrations and mucosal folds. Bowel wall thickness was measured perpendicular to the wall from the internal interface between the lumen and mucosa to the external interface between the serosa and muscularis propria (Dell'Era et al., 2023).
- g) Color or power Doppler ultrasound imaging was used to determine and grade the vascularity within bowel wall segments. Vascularity on color Doppler imaging was considered when coloured pixels were consistently reproduced at the same location (Nassef et al., 2014).

- h) To assess the mesentery, the transducer was placed in the epigastrium at the duodenojejunal flexure, which runs obliquely towards the right iliac fossa. The participant was instructed to breathe in deeply, and out. As they exhaled, pressure was gently applied to the transducer to improve the visualisation of the mesentery and superior mesenteric artery, to exclude or confirm lymphadenopathy and fatty wrapping.
 - i) During the examination, the bowel was assessed for the presence of inflammatory conditions, using the potential BUS parameters as a guide. The presence of inflammatory activity was documented as positive (active) or negative (inactive). Inflammation was deemed to be present if there was bowel wall thickening (bowel wall thickness > 3 mm) and the presence of any additional established indicators or parameters of inflammation, including increased vascularity in the bowel wall, loss of bowel wall stratification, loss of haustration, fatty wrapping (mesenteric inflammatory fat), mesenteric lymph nodes and free fluid. The bowel was also evaluated for complications, including luminal stenoses, fistulas and intra-abdominal abscesses, which, if present, were described and recorded.
 - j) The ultrasound findings and images were recorded and stored on the PACS for interpretation by the consultant radiologist, who generated the ultrasound report – the preliminary IBD diagnosis.
- 3) The sonographer completed the ultrasound checklist after the ultrasound scan. The sonographer and the consultant radiologist discussed the findings of the checklist and the images stored on PACS.
 - 4) The consultant radiologist compiled a radiological report, which is referred to in this study as a preliminary IBD diagnosis.
 - 5) The consultant radiologist then signed off on this report.

3.5.3 Phase 3: Comparing the preliminary and confirmatory diagnosis of inflammatory bowel disease

The confirmatory diagnosis of each patient had to be obtained before the preliminary diagnosis of IBD using ultrasound was compared with the confirmatory diagnoses. The confirmatory diagnosis comprised a patient's histological report of the biopsy taken during a colonoscopy. The preliminary diagnostic reports of the patients' BUS scans were retrieved from PACS, the confirmatory histology reports were retrieved from the MEDITECH platform for patients of the public hospital, and the participant hospital files for patients of the private hospital. An Excel data sheet was prepared in the following manner:

- 1) A data sheet with the 77 ID numbers of the participating patients and column headings for the preliminary and confirmatory diagnoses, as well as the biographical data of the participating patients; and
- 2) The measurements of the different variables of the preliminary diagnosis, as well as the preliminary ultrasound diagnosis; and
- 3) The confirmatory diagnoses were recorded on the spreadsheet.
- 4) After capturing the data on the Excel spreadsheet, the data were checked for accuracy, duplication, and missing data, by comparing the hardcopy checklist sheets against the Excel spreadsheet.
- 5) Similarly, the confirmatory diagnoses were also checked.

3.5.4 Phase 4: Analysing data

The statistical analysis of the data of this study was performed with SAS Version 9.2 under the guidance of a statistician. Descriptive statistics, including nominal frequencies and percentages, were calculated for the categorical data and means or medians and percentiles were calculated for the numerical data. The Shapiro-Wilk test was performed to ascertain if numerical data followed a

normal distribution. To compare the accuracy of BUS preliminary diagnosis of IBD with the confirmatory diagnosis of IBD, Fisher's exact tests were performed to accommodate groups of less than five. Fisher's exact test was performed to determine if a statistically significant association existed between two variables, preliminary IBD diagnosis using ultrasound and confirmed IBD diagnosis using histological examination (Bind & Rubin, 2020). These tests were performed using different sets of count data at a significance level of .05. The null hypothesis that was considered is:

H₀: There is no association between preliminary IBD diagnosis using ultrasound and confirmed IBD diagnosis using histological examination.

To compare the accuracy of the BUS parameters in the diagnosis of IBD with colonoscopy with a biopsy, accuracy estimate calculations and independence tests were performed. Fisher's exact test was performed to determine if there was an association between the preliminary diagnosis of IBD using the individual BUS and the confirmation of IBD using histological analysis. The accuracy estimates were determined for the individual BUS parameters, as well as for the preliminary ultrasound diagnosis, using true positive and true negative diagnoses.

The accuracy of a test is its ability to correctly differentiate between abnormal cases and healthy cases. It is calculated by the total number of true positive cases (TP) plus the total number of true negatives (TN) divided by the total cases (Baratloo et al., 2015; Zaborowska & Loo, 2023). The true positive cases were all the cases for which ultrasound positively identified the parameter, and for which the final histology results were positive. The true negative cases were all the cases where the ultrasound results were negative (did not identify the parameter), and the final histology results were also negative. The total cases were all the participants in the study. The following formula for accuracy was used (Baratloo et al., 2015; Zaborowska & Loo, 2023):

The formula for Accuracy = $(TP + TN) / (Total\ cases)$

Figure 3.1 illustrates the data-capturing processes and data analysis steps.

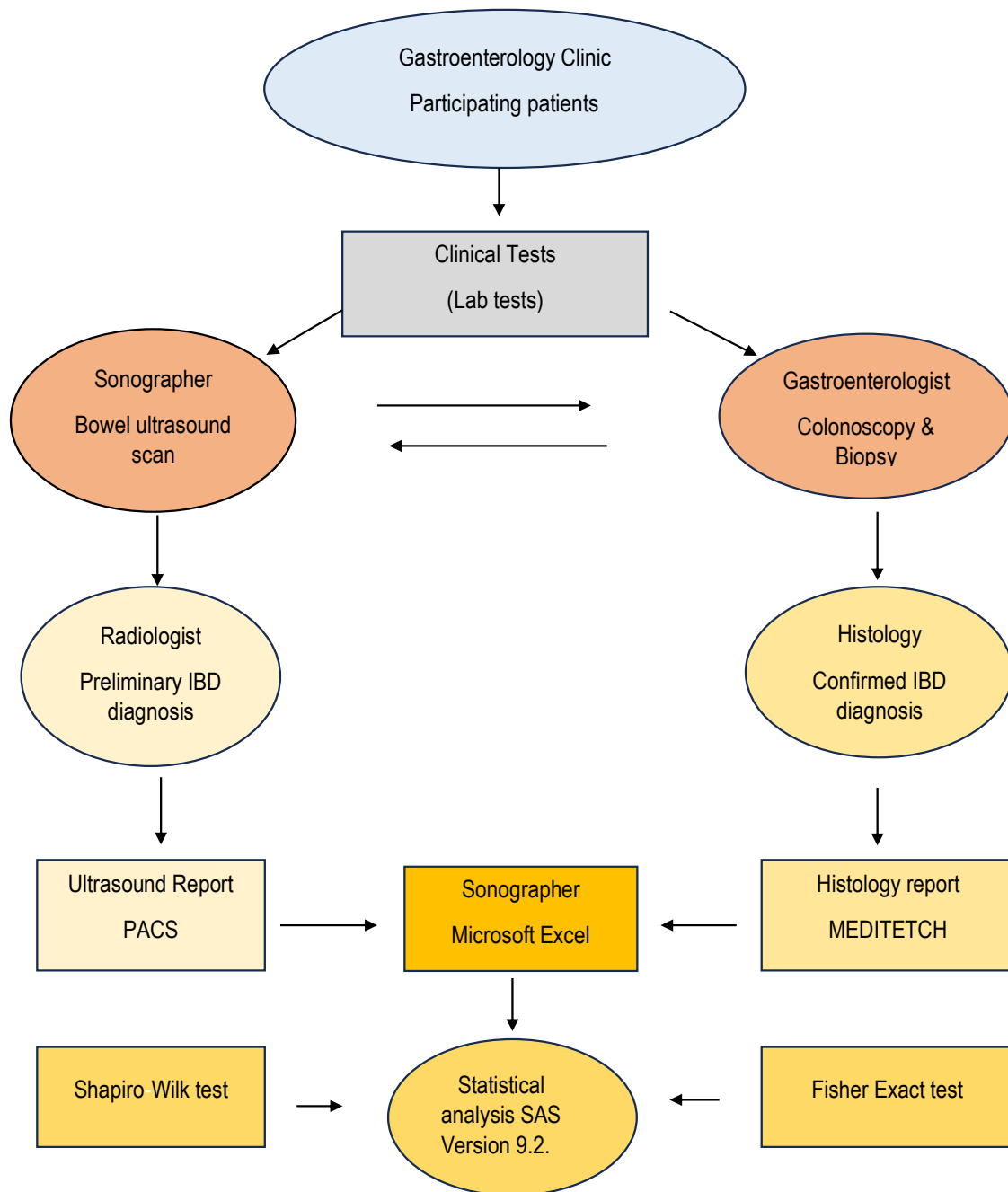


Figure 3.1 Flow diagram of the data-capturing and analysis steps

3.6 Validity and reliability of the data

3.6.1 Validity

Validity determines the truthfulness of the research results (Heale & Twycross, 2015). The validity of this research was ensured by careful planning of the ultrasound guide by referencing information from trustworthy sources in the literature. The researcher (sonographer) worked with a consultant radiologist who interpreted and confirmed the ultrasound findings. The same sonographer performed the ultrasound scans on all participating patients, and the same radiologist produced the final ultrasound reports. The radiologist who generated the final ultrasound report in this study has a PhD in radiology and has worked as a consultant radiologist for more than 15 years. The researcher is a qualified sonographer with a BTech degree in ultrasound and 21 years of clinical experience performing abdominal ultrasound. The radiologist and sonographer were blinded from the colonoscopy, histology findings, and biomarkers. A registered statistician performed the data analysis. A professional member of the European Medical Writers Association performed language editing.

3.6.2 Reliability

Reliability relates to the consistency of a research instrument (Heale & Twycross, 2015) or the possibility of repeating the research and achieving the same results (Leung, 2015). As the EFSUMB ultrasound guidelines for IBD recommended, a standardised ultrasound technique and established standardised ultrasound parameters were used to conduct the study, which makes ultrasound an imaging modality that is easy to use, with good repeatability and accuracy. Also, the radiologist who interpreted and confirmed the ultrasound findings is a professional who specialises in image interpretation. All data in this research study was accounted for by transferring data directly from the checklist and final ultrasound reports to Excel spreadsheets. The checklists were given serial



numbers (unique ID numbers) to anonymise the data. The diagnoses or findings of all participating patients were kept confidential. A pilot study was included.

Chapter 4

Preliminary and Confirmatory Diagnosis of Inflammatory

Bowel Disease

4.1 Introduction

A research instrument containing eight potential BUS parameters was developed to capture patient data during an ultrasound scan and make a preliminary diagnosis of IBD. The research instrument was used to capture the presence or absence of each BUS parameter of 77 participants who presented with and were referred for suspected IBD. The presence or absence of each BUS parameter on the ultrasound scan was captured and used to make a preliminary diagnosis. The final diagnosis of IBD was confirmed by a histological assessment for each of these patients. The patients underwent a colonoscopy with a biopsy. To ascertain the accuracy of BUS compared to colonoscopy with biopsy for diagnosing IBD, a comparative accuracy study was conducted between the preliminary diagnosis of IBD using ultrasound and the confirmed IBD diagnosis using histology analysis (from the colonoscopy with a biopsy).

4.2 Biographical information of the sample population

A total of 77 participants representing different age groups participated in this study. The ages of the participating patients ranged from 19 years to 85 years, with the mean age being 46 years (Figure 4.1). The gender distribution of the participants in the study was almost similar, with 39 (50.7%) being men and 38 (49.4%) being women.

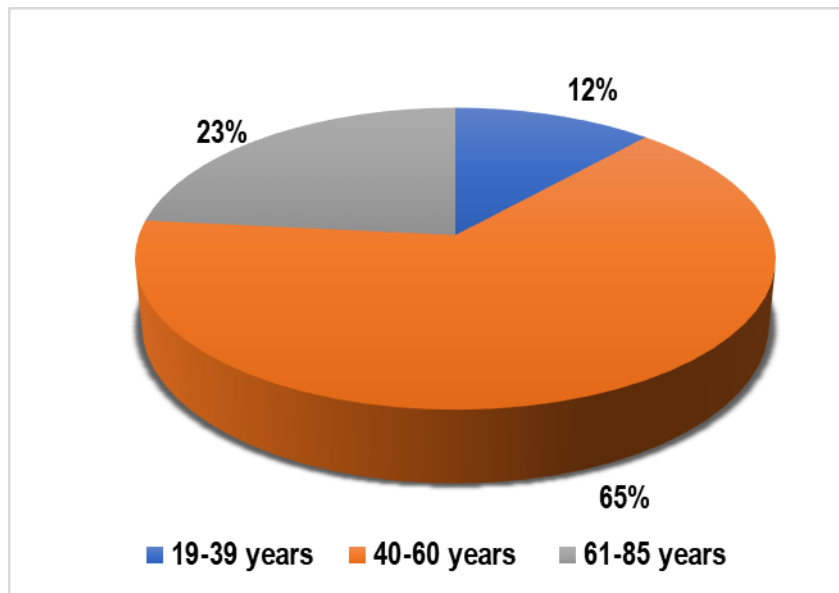


Figure 4.1 Percentages of participants in different age intervals

Various ethnic groups were represented by the participating patients, namely, Black, White, Coloured, and Indian. Approximately 53% of the patients were from the Black ethnic group, while 2.6% of patients were from the Indian ethnic group (Figure 4.2). Most participants in the Black ethnic group were men. Severe inflammatory bowel conditions were more commonly seen in the Black and Indian ethnic groups than in the other two ethnic groups. All the participants underwent an abdominal ultrasound scan, including of the bowel, to establish the preliminary IBD diagnosis.

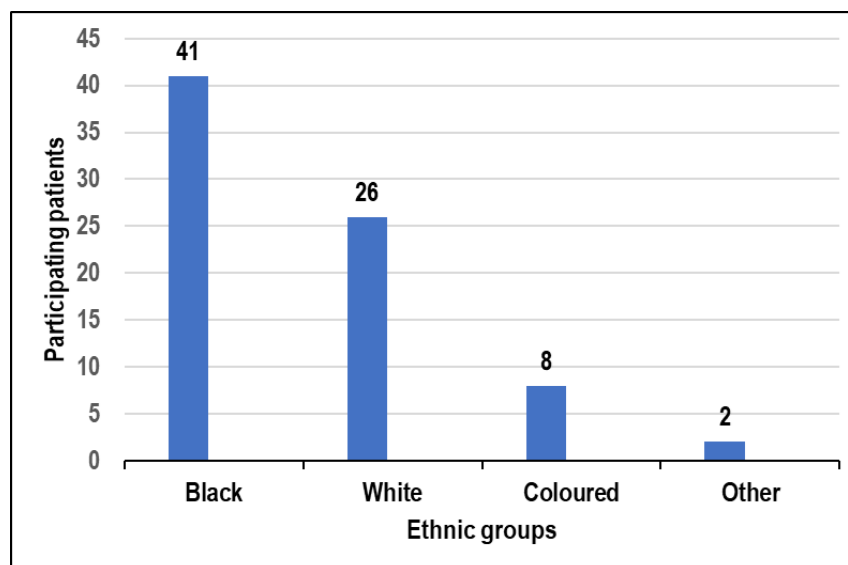


Figure 4.2 **Number of participants representing different ethnic groups (other represents the Indian ethnic group in this study)**

4.3 Preliminary diagnosis of inflammatory bowel disease using the bowel ultrasound parameters

4.3.1 Presentation of bowel ultrasound parameter measurements

The ultrasound measurements of the different BUS parameters showed various ultrasound patterns of the bowel for patients diagnosed positive with IBD and for patients diagnosed negative for IBD.

Error! Reference source not found.¹ provides descriptions of the different potential BUS parameter measurements demonstrated by this study.

Table 4.1 Descriptions of measurements found for the different potential BUS parameters

Potential BUS parameter	Description of BUS parameter measurements
Bowel wall thickness	Bowel wall thickness of patients with suspected IBD ranged from 4 to 10 mm, with a mean thickness of 4.5 mm. The range of bowel wall thickness of patients who were diagnosed as negative for IBD ranged from 2 to 3 mm.
Vascularity	Increased vascularity in patients with suspected IBD was identified using color Doppler signal and seen within the inflamed or thickened bowel wall. Normal or no vascularity was noted in patients confirmed to have negative IBD diagnoses.
Bowel wall stratification	Focal or extensive disruption of the bowel wall layers was seen in patients with suspected IBD with a thickened bowel wall and a positive IBD diagnosis. Most patients (positive and negative cases) demonstrated a preserved stratification of the bowel wall.
Haustration	Loss of haustration was seen in the colonic bowel segments of patients with suspected IBD in the positively IBD-diagnosed participants, while all confirmed IBD negative cases and some of the confirmed positive cases showed normal bowel haustration.
Fatty wrapping	Hyperechoic/echogenic, almost solid tissue (inflamed fat) was seen surrounding the inflamed bowel segment of patients with suspected IBD, while this was not seen in normal IBD cases.
Peristalsis	An absence of peristalsis was seen in noncompressible bowel segments of patients with suspected IBD with a positive IBD diagnosis. Good peristalsis was seen in the bowel segments of patients with a normal study (negative IBD).
Mesenteric lymph nodes	Round and oval-shaped hypoechoic or reactive lymph nodes of varying sizes were seen in patients with suspected IBD, as well as in participants with non-IBD-related cases.
Free fluid	Free fluid close to the inflamed bowel was seen in patients with suspected IBD; this was also present in non-IBD-related cases.

Ultrasound images of the participating patients with suspected IBD were taken to visualise presentations of the eight potential BUS parameters. The image in Figure 4.3 A shows a hypoechoic thickened bowel wall of a patient; the bowel wall measured 5.6 mm thicker than the cut-off value of 3 mm for a normal bowel wall. The image in Figure 4.3 B shows a patient's abnormally thickened bowel wall with increased vascularity, which had been identified using color Doppler signal of the bowel wall. A high degree of inflammation of the bowel wall can disrupt the stratification of the bowel wall layer, either focally or extensively. The image in Figure 4.3 C demonstrates the disruption of the stratification of an inflamed bowel wall layer (arrow), which may indicate severe active bowel disease. The image in Figure 4.3 D shows the loss of haustration of a bowel segment of a patient with chronic IBD. The presence of a bright fatty wrapping around an inflamed bowel segment (arrows), as shown in Figure 4.3 E, can also help identify inflamed pathologic areas in the bowel segments. These fatty wrappings were common in active Crohn's disease. In participants where the bowel wall has stiffened, this leads to a lack of peristalsis and compressibility. The image in Figure 4.3 F shows a bowel segment with a thickened wall, poor peristalsis, and a lack of compressibility (arrows). The image in Figure 4.3 G shows hypoechoic (reactive) mesenteric lymph nodes measuring up to 6.6 mm in diameter (arrows), which was present in a patient with active IBD, and the image in Figure 4.3 H shows free fluid (arrows), which was seen in participants with active IBD.



Figure 4.3 A

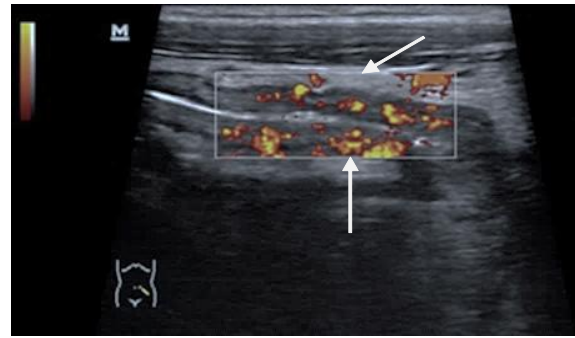


Figure 4.3 B

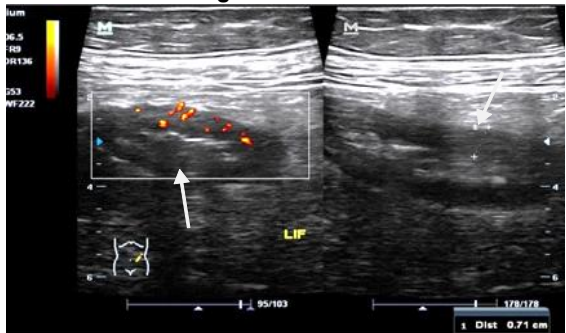


Figure 4.3 C

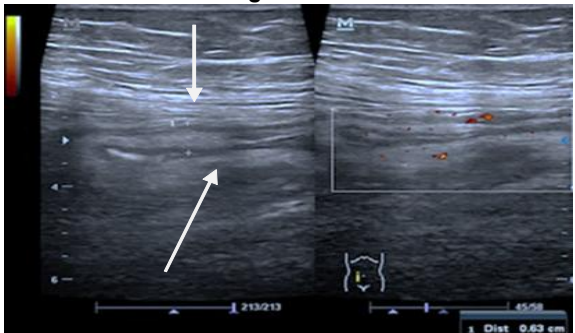


Figure 4.3 D

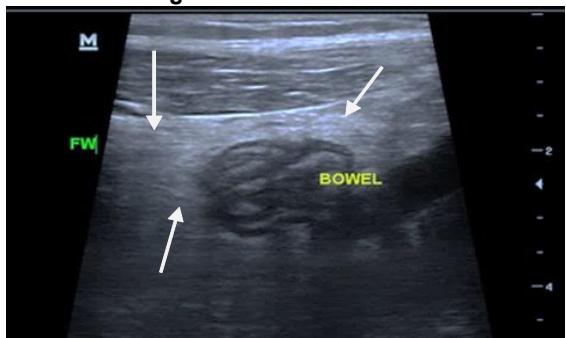


Figure 4.3 E

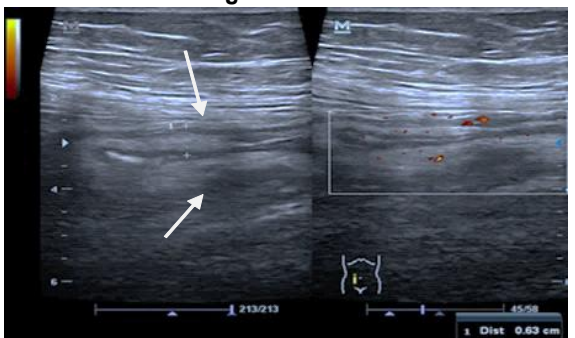


Figure 4.3 F



Figure 4.3 G

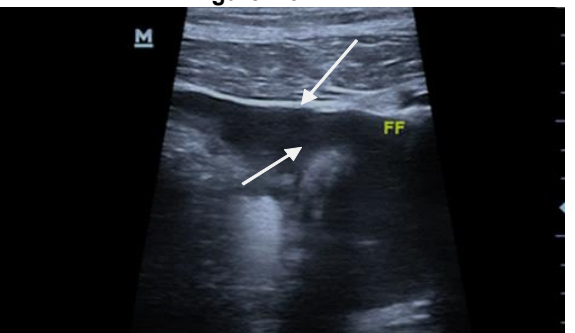


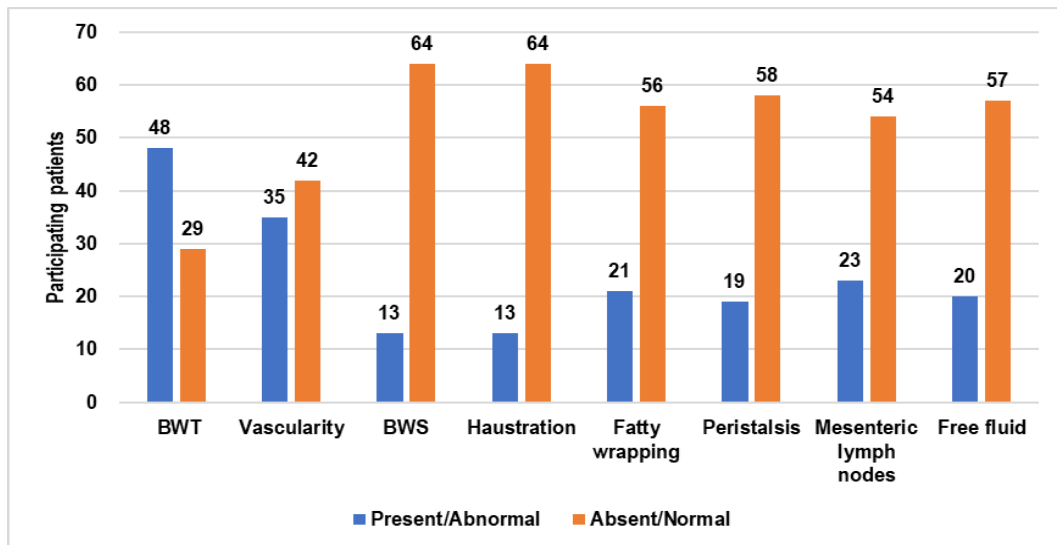
Figure 4.3 H

Figure 4.3 BUS images showing examples of presentations of potential BUS parameters used for the diagnosis of suspected IBD. Figure 4.4 A: Increased bowel wall thickness (= 5.6 mm); Figure 4.3 B: Thickened bowel wall with increased vascularity; Figure 4.3

C: Bowel segment with loss of bowel wall stratification; D: Thickened bowel segment with loss of haustration; Figure 4.3 E: Fatty wrapping around a diseased bowel segment; Figure 4.3 F: Thickened bowel loop with poor peristalsis (bowel wall thickness = 6.2 mm); Figure 4.3 G: Hypoechoic mesenteric lymph nodes (size of lymph nodes = 4.4 mm; 6.6 mm; 5.1mm in diameter); Figure 4.3 H: Free fluid

4.3.2 Preliminary inflammatory bowel disease ultrasound diagnosis using the eight bowel ultrasound parameter measurements

The research instrument that was developed for this study was applied during the ultrasound scan of participating patients with suspected IBD. Of the 77 participants who were scanned, ultrasound diagnosed 48 (62.3%) with suspected IBD, and 29 (37.7%) were diagnosed with negative IBD. IBD was considered to be present if there was a thickened bowel wall. A combination of a thickened bowel wall and the presence of any additional potential BUS parameters made the diagnosis of IBD stronger and more reliable. More than 60% of the participants in this study had thickened bowel walls (**Error! Reference source not found.**4). Increased vascularity in the bowel wall (45.5%) was the second-most frequently occurring IBD parameter noted with ultrasound. Positive measurements for suspected IBD of the other six BUS parameters were relatively low, ranging from 29.9% of the participants showing the presence of mesenteric lymph nodes, to 16.8% of the participants being found with focal or extensive disruption of bowel wall layers and 16.8% participants showing loss of haustration of the colonic bowel segments.



Note. BWT = Bowel wall thickness, BWS = Bowel wall stratification

Figure 4.5 Number of participants showing suspected IBD using the potential BUS parameters and number of patients diagnosed negative for IBD

In an attempt to identify a possible pattern in the preliminary ultrasound diagnosis made with the eight BUS parameters, a table was drawn up to delineate the positive and negative preliminary diagnosis. Though a structural and clear pattern could not be identified, it was noted that the preliminary diagnosis showed all the participants with suspected IBD or positive ultrasound diagnosis having thickened bowel walls (Table 4.2). Most of the participants with positive preliminary diagnoses also showed thickened bowel walls, with a combination of the additional parameters of IBD. The preliminary diagnoses also showed that none of the eight BUS parameters were present in all the participants with negative preliminary diagnoses.



Table 4.2 Preliminary IBD ultrasound diagnosis (yellow shaded blocks) according to the BUS parameters (green shaded blocks)

Patient No.	Preliminary diagnosis using potential BUS parameters								Preliminary IBD diagnosis
	Bowel wall thickness	Vascularity	BWS	Haustration	Fatty wrapping	Peristalsis	Lymph nodes	Free fluid	
1	P	P	P	P	N	P	P	P	+
2	P	P	P	P	P	P	P	P	+
3	P	P	P	P	P	P	P	P	+
4	N	N	N	N	N	N	N	N	-
5	P	P	P	P	P	P	P	P	+
6	N	N	N	N	N	N	N	N	-
7	P	P	N	N	N	N	N	N	+
8	N	N	N	N	N	N	P	N	-
9	N	N	N	N	N	N	N	N	-
10	P	N	N	N	N	N	N	P	+
11	P	P	P	P	N	N	N	N	+
12	P	P	N	N	N	N	N	N	+
13	P	P	P	P	P	P	N	N	+
14	P	P	P	P	N	P	N	P	+
15	N	N	N	N	N	N	N	N	-
16	P	P	P	P	N	N	P	P	+
17	N	N	N	N	N	N	N	N	-
18	N	N	N	N	N	N	P	N	-
19	P	P	P	P	P	P	N	P	+
20	P	P	P	P	N	N	P	N	+
21	P	P	P	P	P	P	P	P	+
22	P	P	P	P	P	P	P	N	+
23	P	N	N	N	N	N	N	N	+
24	P	P	P	P	P	N	N	N	+
25	P	P	N	N	N	N	N	N	+
26	P	N	N	N	N	N	N	P	+
27	P	P	N	N	N	N	P	N	+
28	N	N	N	N	N	N	N	N	-
29	N	N	N	N	N	N	N	N	-
30	P	N	N	N	N	N	N	N	+
31	N	N	N	N	N	N	N	P	-
32	N	N	N	N	N	N	N	N	-
33	N	N	N	N	N	N	N	N	-
34	P	P	N	N	N	N	N	N	+
35	N	N	N	N	N	N	N	N	-
36	N	N	N	N	N	N	N	N	-



Patient No.	Preliminary diagnosis using potential BUS parameters								Preliminary IBD diagnosis
	Bowel wall thickness	Vascularity	BWS	Haustration	Fatty wrapping	Peristalsis	Lymph nodes	Free fluid	
37	N	N	N	N	N	N	N	N	-
38	P	P	N	N	P	P	P	N	+
39	N	N	N	N	N	N	N	N	-
40	N	N	N	N	N	N	N	N	-
41	P	P	N	N	P	P	P	P	+
42	P	P	N	N	P	P	N	N	+
43	N	N	N	N	N	N	N	N	-
44	N	N	N	N	N	N	N	N	-
45	P	P	N	N	P	P	N	P	+
46	P	P	N	N	P	P	P	N	+
47	N	N	N	N	N	N	N	P	-
48	N	P	N	N	P	N	N	P	+
49	P	P	N	N	P	P	P	N	+
50	N	N	N	N	N	N	N	N	-
51	P	P	N	N	P	P	P	P	+
52	P	N	N	N	N	N	P	N	+
53	P	P	N	N	N	N	N	P	+
54	N	N	N	N	N	N	N	N	-
55	N	N	N	N	N	N	N	N	-
56	P	P	N	N	P	N	P	N	+
57	N	N	N	N	N	N	N	N	-
58	P	N	N	N	N	N	P	P	+
59	P	P	N	N	N	N	N	N	+
60	P	P	N	N	N	N	N	N	+
61	N	N	N	N	N	N	N	N	-
62	P	N	N	N	N	N	N	N	+
63	N	N	N	N	N	N	N	N	-
64	P	N	N	N	N	N	P	N	+
65	P	N	N	N	N	N	N	N	+
66	P	P	N	N	P	N	N	N	+
67	N	N	N	N	N	N	N	P	-
68	P	N	N	N	N	P	P	N	+
69	P	N	N	N	N	N	N	N	+
70	N	N	N	N	N	N	N	N	-
71	P	N	N	N	N	N	N	N	+
72	P	P	N	N	N	N	N	N	+
73	P	P	N	N	N	N	P	N	+
74	P	P	N	N	P	P	N	N	+



Patient No.	Preliminary diagnosis using potential BUS parameters								Preliminary IBD diagnosis
	Bowel wall thickness	Vascularity	BWS	Haustration	Fatty wrapping	Peristalsis	Lymph nodes	Free fluid	
75	P	P	N	N	N	N	N	N	+
76	N	N	P	P	A	N	N	N	-
77	P	N	N	N	N	N	N	P	+

Note. BWT = bowel wall thickness; BWS = bowel wall stratification; P = positive diagnosis for suspected IBD; N = negative diagnosis for IBD

During the ultrasound scans, ancillary intra-abdominal pathologies were also detected in some of the participating patients. These findings may indicate potential health issues, either benign or more serious conditions, such as gallstones or portal vein thromboses. Further medical evaluation and management will be necessary for individuals with these findings. **Error! Reference source not found.**3 shows the ancillary abdominal pathologies detected in some participants.

Table 4.3 Number of participants for whom ancillary intra-abdominal pathologies were identified during the ultrasound scan

Ancillary pathology	Number of participants (n = 65)
Fatty liver/liver pathology	19
Splenomegaly	3
Pancreas pathology	1
Gallbladder pathology	11
Hyperechoic kidneys/renal pathology	11
Umbilical hernia	1
Bile duct dilatation	2
Gastritis	3
Portal vein thrombus	1
Pleural effusion	4
Rectal mass	3
Enlarged (myomatous) uterus pathology	2
Ovarian mass	2
Enlarged prostate	2

4.4 Confirmation of preliminary diagnoses of inflammatory bowel disease

The number of participants diagnosed with IBD in the preliminary examination was compared to the number of participants confirmed to have IBD through histological procedures. In the preliminary ultrasound examination, 16.8% more patients were diagnosed positive for IBD than by the confirmed diagnoses ().

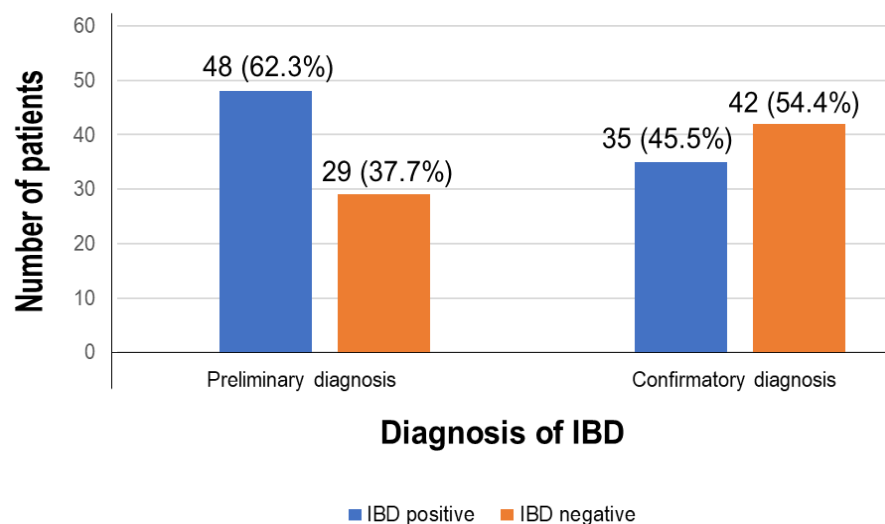


Figure 4.6 Comparison of the number of participants diagnosed with or without inflammatory bowel disease in preliminary and confirmatory diagnoses

To determine the extent to which the preliminary ultrasound diagnoses were accurate, the preliminary diagnosis was compared to the confirmed diagnosis. In an attempt to compare the preliminary diagnosis with the confirmed IBD diagnosis, a table was drawn up. For the 77 participating patients, the preliminary diagnosis was incorrect in approximately 17% (white blocks, Table 4.4). However, these participants demonstrated a thickened bowel wall on the scan, and none of them were diagnosed with IBD through histology. The histology results of these participants showed other bowel pathologies, such as diverticulitis, polyps and bowel tumours. The findings of these noninflammatory bowel pathologies may indicate potential health issues, which could be benign or more serious conditions. Further medical evaluation and management may be required for

these individuals. For the remainder of the preliminary diagnosis, 83% were all correctly diagnosed with ultrasound using the BUS parameters. One participant, who showed a thickened bowel wall, loss of bowel wall stratification, and narrowing of the lumen, was diagnosed with stenosis at the ascending colon through a histological procedure. This complication of IBD also was positively identified with ultrasound.

Table 4.4 Presence of IBD ultrasound diagnoses versus confirmed diagnosis of IBD

Patient No.	Preliminary diagnosis using potential BUS parameters								Preliminary IBD diagnosis	Confirmatory IBD diagnosis	Number of BUS parameters that gave positive IBD diagnoses
	BWT	Vascularity	BWS	Haustration	Fatty wrapping	Peristalsis	Lymph nodes	Free fluid			
1	P	P	P	P	N	P	P	P	+	+	7
2	P	P	P	P	P	P	P	P	+	+	8
3	P	P	P	P	P	P	P	P	+	+	8
4	N	N	N	N	N	N	N	N	-	-	0
5	P	P	P	P	P	P	P	P	+	+	8
6	N	N	N	N	N	N	N	N	-	-	0
7	P	P	N	N	N	N	N	N	+	+	2
8	N	N	N	N	N	N	P	N	-	-	1
9	N	N	N	N	N	N	N	N	-	-	0
10	P	N	N	N	N	N	N	P	+	+	2
11	P	P	P	P	N	N	N	N	+	+	4
12	P	P	N	N	N	N	N	N	+	-	2
13	P	P	P	P	P	P	N	N	+	+	6
14	P	P	P	P	N	P	N	P	+	+	6
15	N	N	N	N	N	N	N	N	-	-	0
16	P	P	P	P	N	N	P	P	+	+	6
17	N	N	N	N	N	N	N	N	-	-	0
18	N	N	N	N	N	N	P	N	-	-	1
19	P	P	P	P	P	P	N	P	+	+	7
20	P	P	P	P	N	N	P	N	+	+	5
21	P	P	P	P	P	P	P	P	+	+	8
22	P	P	P	P	P	P	P	N	+	-	7
23	P	N	N	N	N	N	N	N	+	-	1
24	P	P	P	P	P	N	N	N	+	+	5
25	P	P	N	N	N	N	N	N	+	-	2
26	P	N	N	N	N	N	N	P	+	+	2
27	P	P	N	N	N	N	P	N	+	+	3
28	N	N	N	N	N	N	N	N	-	-	0



Patient No.	Preliminary diagnosis using potential BUS parameters								Preliminary IBD diagnosis	Confirmatory IBD diagnosis	Number of BUS parameters that gave positive IBD diagnoses
	BWT	Vascularity	BWS	Haustration	Fatty wrapping	Peristalsis	Lymph nodes	Free fluid			
29	N	N	N	N	N	N	N	N	-	-	0
30	P	N	N	N	N	N	N	N	+	+	1
31	N	N	N	N	N	N	N	P	-	-	1
32	N	N	N	N	N	N	N	N	-	-	0
33	N	N	N	N	N	N	N	N	-	-	0
34	P	P	N	N	N	N	N	N	+	-	5
35	N	N	N	N	N	N	N	N	-	-	0
36	N	N	N	N	N	N	N	N	-	-	0
37	N	N	N	N	N	N	N	N	-	-	0
38	P	P	N	N	P	P	P	N	+	-	5
39	N	N	N	N	N	N	N	N	-	-	0
40	N	N	N	N	N	N	N	N	-	-	0
41	P	P	N	N	P	P	P	P	+	+	6
42	P	P	N	N	P	P	N	N	+	+	4
43	N	N	N	N	N	N	N	N	-	-	0
44	N	N	N	N	N	N	N	N	-	-	0
45	P	P	N	N	P	P	N	P	+	+	5
46	P	P	N	N	P	P	P	N	+	+	5
47	N	N	N	N	P	N	N	P	-	-	2
48	P	P	N	N	P	N	N	P	+	+	4
49	P	P	N	N	P	P	P	N	+	+	5
50	N	N	N	N	N	N	N	N	-	-	0
51	P	P	N	N	P	P	P	P	+	+	6
52	P	N	N	N	N	N	P	N	+	+	2
53	P	P	N	N	N	N	N	P	+	+	3
54	N	N	N	N	N	N	N	N	-	-	0
55	N	N	N	N	N	N	N	N	-	-	0
56	P	P	N	N	P	N	P	N	+	+	4
57	N	N	N	N	N	N	N	N	-	-	0
58	P	N	N	N	N	N	P	P	+	-	3
59	P	P	N	N	N	N	N	N	+	+	2
60	P	P	N	N	N	N	N	N	+	+	2
61	N	N	N	N	N	N	N	N	-	-	0
62	P	N	N	N	N	N	N	N	+	+	1
63	N	N	N	N	N	N	N	N	-	-	0
64	P	N	N	N	N	N	P	N	+	-	2
65	P	N	N	N	N	N	N	N	+	+	1
66	P	P	N	N	P	N	N	N	+	+	3
67	N	N	N	N	N	N	N	P	-	-	1

Patient No.	Preliminary diagnosis using potential BUS parameters								Preliminary IBD diagnosis	Confirmatory IBD diagnosis	Number of BUS parameters that gave positive IBD diagnoses
	BWT	Vascularity	BWS	Haustration	Fatty wrapping	Peristalsis	Lymph nodes	Free fluid			
68	P	N	N	N	N	P	P	N	+	+	3
69	P	N	N	N	N	N	N	N	+	-	1
70	N	N	N	N	N	N	N	N	-	-	0
71	P	N	N	N	N	N	N	N	+	-	1
72	P	P	N	N	N	N	N	N	+	-	2
73	P	P	N	N	N	N	P	N	+	+	3
74	P	P	N	N	P	P	N	N	+	+	4
75	P	P	N	N	N	N	N	N	+	-	2
76	N	N	N	N	N	N	N	N	-	-	0
77	P	N	N	N	N	N	N	P	+	-	2

Note. BWT = Bowel wall thickness, P = positive IBD diagnosis, N = negative IBD diagnosis

The number of BUS parameters that gave positive and negative diagnoses for IBD were counted to determine if a diagnostic pattern could be identified. If a participant was diagnosed with suspected IBD with all eight parameters, the diagnoses were confirmed by a histological examination for all the patients (

5). The converse was also true for when a negative diagnosis by all BUS parameters was confirmed in all patients. Participants with less than eight but more than zero positive BUS parameter diagnoses resulted in positive or negative confirmed diagnoses. It can be concluded that a pattern based on the number of BUS parameters could not be established with this small sample of participants.

Table 4.5 Numbers and percentages of positive and negative BUS parameter diagnoses for IBD

Number of BUS parameters (n = 8)	Number of participating patients (n = 77)	Number BUS parameters confirmed positive for IBD (%)	Number BUS parameters confirmed negative for IBD (%)
8	4	4 (100)	0
7	3	2 (66.7)	1 (33.3)
6	5	5 (100)	0
5	7	5 (71.4)	2 (28.6)
4	5	5 (100)	0
3	6	5 (83.3)	1 (16.7)
2	13	6 (46.2)	7 (53.8)
1	10	3 (30)	7 (70)
0	24	0	24 (100)
Total	77	35	42

4.5 Comparison of the preliminary diagnosis and confirmation of inflammatory bowel disease

4.5.1 Accuracy estimates

Several accuracy estimates were calculated to determine whether the BUS parameters can be used in ultrasound scans as an IBD diagnostic measure. The accuracy estimates were determined for the individual BUS parameters and for the preliminary ultrasound diagnoses using true positive and true negative diagnoses (Baratloo et al., 2015; Zaborowska & Loo, 2023). The two BUS parameters, bowel wall thickness and vascularity, delivered accuracy estimates greater than 80% (**Error!**

Reference source not found..6). The accuracy estimates of the remainder of the BUS parameters were all less than 75%. Interestingly, the accuracy estimate of the preliminary diagnosis was also relatively high.

Table 4.6 Accuracy estimates of all BUS parameters as diagnostic measures for IBD

BUS parameter	True positive diagnosis	True negative diagnosis	Accuracy
Bowel wall thickness	35	29	83.1
Vascularity	28	35	81.8
Bowel wall stratification	12	41	68.8
Haustration	12	41	68.8
Fatty wrapping	17	38	71.4
Mesenteric lymph nodes	16	35	66.2
Peristalsis	16	39	71.4
Free fluid	15	37	67.5
Overall accuracy	35	28	81.8

4.5.2 Independence tests

Fisher's exact tests were performed to determine if a statistically significant association existed between the two variables, preliminary IBD diagnosis using ultrasound and confirmed IBD diagnosis using histological examination. These tests were performed using different sets of count data at a significance level of 0,05. The null hypothesis that was considered was:

H_0 : There is no association between preliminary IBD diagnosis using ultrasound and confirmed IBD diagnosis using histological examination.

Bowel wall thickness

To determine if there is an association between the preliminary diagnosis of IBD using bowel wall thickness and the confirmation of IBD using histological analysis, the numbers of participants in the different diagnostic categories were counted. For participants diagnosed with positive preliminary IBD diagnoses using ultrasound, approximately a quarter of these diagnoses were confirmed to be negative. All preliminary negatively diagnosed IBD using bowel wall thickness were all accurately confirmed to be negative (Table 4.7). A Fisher's exact test revealed there was a significant association between the preliminary diagnosis of IBD using the bowel wall thickness as determined by ultrasound measurements and the confirmation of IBD through histology (two-tailed $p < 0.00001$). Therefore, the null hypothesis is rejected.

Table 4.7 Contingency table for bowel wall thickness comparing participant numbers for preliminary IBD diagnosis and confirmed IBD diagnosis

BWT	Confirmed IBD positive diagnoses (%)	Confirmed IBD negative diagnoses (%)	Total
Ultrasound IBD positive diagnosis (%)	35 (72.9)	13 (27.1)	48
Ultrasound IBD negative diagnosis (%)	0 (0)	29 (100)	29
Total	35	42	77

Vascularity

To determine if there was an association between the preliminary diagnosis of IBD using the second BUS parameter, vascularity, and the confirmation of IBD using histological analysis, the same

calculations were performed as for bowel wall thickness. Of the positive preliminary IBD diagnoses using ultrasound, a quarter were confirmed to be negative, and from the preliminary negative diagnosed IBD using vascularity, more than 80% were accurately confirmed to be negative (Table 4.8). The statistical analysis using Fisher's exact test reveals a significant association between the preliminary diagnosis of IBD using vascularity in ultrasound measurements and the confirmation of IBD through histology (two-tailed $p < 0.00001$). Therefore, the null hypothesis is rejected.

Table 4.8 Contingency table for vascularity, comparing participants numbers for preliminary IBD diagnosis and confirmed IBD diagnosis

Vascularity	Confirmed IBD positive diagnoses (%)	Confirmed IBD negative diagnoses (%)	Total
Ultrasound IBD positive diagnosis (%)	28 (80)	7 (20)	35
Ultrasound IBD negative diagnosis (%)	7 (16.7)	35 (83.3)	42
Total	35	42	77

Bowel wall stratification

The analysis to determine if there was an association between the preliminary diagnosis of IBD according to bowel wall stratification and the confirmation of IBD using histological analysis shows that, for the positive preliminary IBD diagnosis with ultrasound, less than 10% of these diagnoses were confirmed to be negative, and of all the preliminary negatively diagnosed IBD using bowel wall stratification, more than 60% were accurately confirmed to be negative (Table 4.9). A Fisher's exact test reveals that a significant association exists between the preliminary diagnosis of IBD using bowel wall stratification in ultrasound measurements and the confirmation of IBD through histology (two-tailed $p < 0.0003$). Therefore, the null hypothesis is rejected.

Table 4.9 Contingency table for bowel wall stratification comparing participant numbers for preliminary IBD diagnosis and confirmed IBD diagnosis

Bowel wall stratification	Confirmed IBD positive diagnoses (%)	Confirmed IBD negative diagnoses (%)	Total
Ultrasound IBD positive diagnosis (%)	12 (92.3)	1 (7.7)	13
Ultrasound IBD negative diagnosis (%)	23 (35.9)	41 (64.1)	64
Total	35	42	77

Haustration

To determine whether there was an association between the preliminary diagnoses of IBD using haustration as a BUS parameter and the confirmation of IBD using histological analysis, the numbers of patients in the different diagnostic categories were counted. It was found that, for the positive preliminary IBD diagnosis with ultrasound, less than 10% of the diagnoses were confirmed to be negative. From the preliminary negatively diagnosed IBD using haustration, more than 60% were accurately confirmed to be negative (Table 4.10). Similar to the other BUS parameters, Fisher's exact test revealed a significant association between the preliminary diagnosis of IBD using haustration in ultrasound measurements and the confirmation of IBD through histology (two-tailed $p = < 0.0003$). Therefore, the null hypothesis is rejected.

Table 4.10 Contingency table for haustration, comparing participant numbers for preliminary IBD diagnosis and confirmed IBD diagnosis

Haustration	Confirmed IBD positive diagnoses (%)	Confirmed IBD negative diagnoses (%)	Total
Ultrasound IBD positive diagnosis (%)	12 (92.3)	1 (7.7)	13
Ultrasound IBD negative diagnosis (%)	23 (35.9)	41 (64.1)	64
Total	35	42	77

Fatty wrapping

To establish whether there is an association between the preliminary diagnosis of IBD on the basis of fatty wrapping and the confirmation of IBD using histological analysis, the numbers of patients in the different diagnostic categories were counted. The data show that, for the positive preliminary IBD diagnosis with ultrasound, less than 20% of these diagnoses were confirmed to be negative, and for all preliminary negative diagnoses of IBD using fatty wrapping, almost 70% were accurately confirmed to be negative (Table 4.11). For the parameter of fatty wrapping, Fisher's exact test reveals a significant association between the preliminary diagnosis of IBD using fatty wrapping in ultrasound measurements and the confirmation of IBD through histology (two-tailed $p < 0.0002$). Therefore, the null hypothesis is rejected.

Table 4.11 Contingency table for fatty wrapping comparing participant numbers for preliminary IBD diagnosis and confirmed IBD diagnosis

Fatty wrapping	Confirmed IBD positive diagnoses (%)	Confirmed IBD negative diagnoses (%)	Total
Ultrasound IBD positive diagnosis (%)	17 (81)	4 (19.1)	21
Ultrasound IBD negative diagnosis (%)	18 (32.1)	38 (67.9)	56
Total	35	42	77

Peristalsis

To determine if there was an association between the preliminary diagnosis of IBD using peristalsis as a BUS parameter and the confirmation of IBD using histological analysis, the numbers of patients in the different diagnostic categories were counted and it was found that, of all the positive preliminary IBD diagnoses using ultrasound, almost 16% were confirmed to be negative. In turn, of preliminary negatively diagnosed IBD using peristalsis, more than 60% were accurately confirmed to be negative (Table 4.12). Fisher's exact test also reveals a significant association between the preliminary diagnosis of IBD using peristalsis via ultrasound measurements and the confirmation of IBD through histology (two-tailed $p < 0.0001$). Therefore, the null hypothesis is rejected.

Table 4.12 Contingency table for peristalsis comparing participant numbers for preliminary IBD diagnosis and confirmed IBD diagnosis

Peristalsis	Confirmed IBD positive diagnoses (%)	Confirmed IBD negative diagnoses (%)	Total
Ultrasound IBD positive diagnosis (%)	16 (84.2)	3 (15.8)	19
Ultrasound IBD negative diagnosis (%)	19 (32.8)	39 (67.2)	58
Total	35	42	77

Mesenteric lymph nodes

The same calculations were performed to determine if there was an association between the preliminary diagnosis of IBD using mesenteric lymph nodes as a BUS parameter and the confirmation of IBD using histological analysis. Of the positive preliminary IBD diagnoses using ultrasound, approximately 30% were confirmed to be negative and of all preliminary negatively diagnosed IBD using mesenteric lymph nodes, about 70% were accurately confirmed to be negative (Table 4.13). A Fisher's exact test reveals there was a significant association between the preliminary diagnosis of IBD using mesenteric lymph nodes in ultrasound measurements and the confirmation of IBD through histology (two-tailed $p < 0.0068$). Therefore, the null hypothesis is rejected.

Table 4.13 Contingency table for mesenteric lymph nodes comparing participant numbers for preliminary IBD diagnosis and confirmed IBD diagnosis

Mesenteric lymph nodes	Confirmed IBD positive diagnoses (%)	Confirmed IBD negative diagnoses (%)	Total
Ultrasound IBD positive diagnosis (%)	16 (69.6)	7 (30.4)	23
Ultrasound IBD negative diagnosis (%)	19 (35.2)	35 (64.8)	44
Total	35	42	77

Free fluid

The numbers of patients in the different diagnostic categories were counted to determine whether there was an association between the preliminary diagnosis of IBD using free fluid as a BUS parameter and the confirmation of IBD using histological analysis. For all the positive preliminary IBD diagnoses using ultrasound, less than 30% were confirmed to be negative and of all the preliminary negative diagnoses of IBD using free fluid, more than 60% were accurately confirmed to be negative (Table 4.14). In this instance, Fisher's exact test reveals a significant association between the preliminary diagnosis of IBD using free fluid in ultrasound measurements and the confirmatory diagnostic procedure of IBD confirmation through histology (two-tailed $p < 0.0035$). Therefore, the null hypothesis is rejected.

Table 4.14 Contingency table for free fluid comparing participant numbers for preliminary IBD diagnosis and confirmed IBD diagnosis

Free fluid	Confirmed IBD positive diagnoses (%)	Confirmed IBD negative diagnoses (%)	Total
Ultrasound IBD positive diagnosis (%)	15 (75)	5 (25)	20
Ultrasound IBD negative diagnosis (%)	20 (35.1)	37 (64.9)	57
Total	35	42	77

Diagnosis procedure

Finally, the numbers of patients in the different diagnostic categories of the preliminary and confirmatory diagnostic procedures were compared. In this study, nearly 50% of the patients were diagnosed with IBD with both ultrasound and a histological examination (**Error! Reference source not found.5**). The percentage of patients who did not have IBD is approximately 40%, as shown by both procedures. False positive diagnoses with ultrasound were less than 20%. The Fisher's exact test established a significant association between the preliminary diagnosis of IBD using ultrasound and the confirmatory diagnostic procedure of IBD confirmation through histology (two-tailed $p < 0.00001$). Because of this statistically significant outcome, the null hypothesis is rejected, and it can be concluded that there was a relationship between the two procedures.

Table 4.15 Contingency table for diagnostic procedure, comparing participant numbers for preliminary IBD diagnosis and confirmed IBD diagnosis

Diagnostic procedure	Confirmed IBD positive diagnoses (%)	Confirmed IBD negative diagnoses (%)	Total
Ultrasound IBD positive diagnosis (%)	35 (45.5)	13 (16.9)	48
Ultrasound IBD negative diagnosis (%)	0 (0)	29 (37.7)	29
Total	35	42	77

4.6 Potential uses of ultrasound for diagnosing inflammatory bowel disease

The results of this study suggest that BUS could be used as a first-line imaging tool to confirm the presence or absence of IBD in patients with suspected IBD. Including BUS in the workup of patients could help determine whether a colonoscopy and biopsy will be needed, or could be avoided. In all the participating patients with a negative preliminary ultrasound diagnosis, the measurements of the eight BUS parameters assessed during the ultrasound scan were within normal limits and confirmed with histology. These findings indicate that a colonoscopy together with a biopsy may not be necessary for patients where the measurements of the eight BUS parameters are normal. In participating patients, where the eight BUS parameters measurements were indicative of IBD, the necessity for a colonoscopy and biopsy could be strongly suggested. However, a study with a larger sample size could provide a better understanding of the role of BUS as a sifting/screening tool in IBD diagnosis.

Chapter 5

Discussion and Conclusion

5.1 Introduction

IBD is a chronic inflammatory condition of the colon and small intestine, which is characterised by chronic inflammation and ulcers along the lining of the digestive tract. IBD causes long-term bowel damage and complications, such as stenosis and perforation, which affect the patient's quality of life. Therefore, early diagnosis of this disease is crucial for the patient suffering from IBD to avoid complications and to ensure effective management of this disease. The current diagnostic approach to diagnose IBD at the public hospital in Bloemfontein, where the study was conducted, is that both BUS and colonoscopy with biopsy are routinely performed to detect IBD in patients suspected to have IBD. It was observed at this hospital that IBD was not present in some of these patients. Furthermore, the invasive nature of colonoscopy and biopsy and the cost of the routine use of both examinations required further investigation, which led to this study. Therefore, the aim was to ascertain the accuracy of BUS compared to a colonoscopy with biopsy for diagnosing IBD. To make a preliminary diagnosis, a group of 77 participants with suspected IBD underwent a BUS scan using several BUS parameters. To ascertain how accurate the preliminary diagnoses of IBD were, the results of these diagnoses were compared to the confirmatory diagnoses through histology of the bowel biopsies. The Fisher's exact test was performed to determine if a statistically significant association existed between the two variables, the BUS IBD diagnosis and the confirmatory IBD diagnosis – using histological examination at a significance level of 0.05. Fisher's exact tests were also performed individually on each BUS parameter to determine if a statistically significant association existed between the different diagnostic patient groups.

5.2 Role of ultrasound in diagnosis of inflammatory bowel disease

In this study, a combination of eight different BUS parameters gleaned from the literature (bowel wall thickness, vascularity, bowel wall stratification, haustration, the presence of fatty wrapping, poor peristalsis, mesenteric lymph nodes, and free fluid) was used to make a preliminary diagnosis of IBD during a BUS scan. The BUS diagnosis of IBD in this study was accurate in more than 80% of the participants in the population. The Fisher's exact test reveals a significant association (significance level of 0.05%) between the preliminary diagnoses of IBD in the participating patients and the confirmatory diagnoses. The accuracy estimates of the BUS parameters for the diagnosis of IBD were greater than 80% for bowel wall thickness and vascularity, while the estimates for the other parameters ranged from 66% to 72%. This outcome is a strong indication that a combination of BUS parameters in the preliminary diagnosis was relatively accurate for diagnosing IBD. This significant outcome was also true for each of the parameters, which indicates the potential usefulness of these parameters to diagnose IBD. This outcome confirms the findings of Dell'Era et al. (2023), who state that the diagnosis of IBD via ultrasound could be more accurate if it relied on a combination of different BUS parameters. All participating patients who were confirmed to have IBD had thickened bowel walls, which confirms the finding of Nassef et al. (2014), who report that a thickened bowel wall could indicate active or chronic IBD. However, the histological analysis in this study also reveals that approximately 17% of the patients who presented with thickened bowel walls visible via ultrasound were not diagnosed with IBD, which is in accordance with Dell'Era et al. (2023), who state that the ultrasound diagnosis of IBD cannot rely on the evaluation of BWT only. The thickened bowel wall in these patients could be attributed to other noninflammatory bowel conditions, such as diverticulitis, polyps and bowel tumours.

5.3 Conclusion

BUS is a non-invasive, accurate imaging tool that could be included in the diagnostic workup as the primary or first-line imaging tool for diagnosing IBD. BUS may serve to expedite diagnosis, decrease the unnecessary use of invasive techniques and reduce medical costs. From this study, it can be concluded that patients with thickened bowel walls should undergo colonoscopy together with biopsy. On the other hand, for the patient with a bowel wall thickness between 2 mm and 3 mm (which is considered normal), a colonoscopy and a biopsy might not be necessary. In patients with normal bowel wall thickness and symptoms that suggest IBD, BUS may be used as a follow-up imaging tool to evaluate the progress of the disease.

Despite the advantages of BUS for diagnosing IBD, this study experienced several limitations, which should be kept in mind when considering similar studies in the future. The sample size of the study was relatively small and limited to one academic public hospital that also serves private patients. A single participating hospital could have influenced the reliability of BUS as an accurate diagnostic tool. Furthermore, it would be advisable for future studies to involve multiple sonographers, because ultrasound is operator-dependent (Haas et al. 2016). Although the results of this study have high accuracy levels and indicate significant associations between BUS and the histological confirmation of IBD, BUS parameters may require refinement, so that they are more precise to serve as an accurate diagnostic tool. For ultrasound to be included in the workup, larger, multicentre studies should be undertaken to clarify the role of BUS in the diagnosis of IBD.

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Appendices

Appendix A: Approval letter from HSREC

UNIVERSITY OF THE
FREE STATE
UNIVERSITEIT VAN DIE
VRYSTAAT
YUNIBESITHI YA
FREISTATA



UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

Health Sciences Research Ethics Committee

11-Nov-2022

Dear Mrs Amanda Hendricks

Ethics Clearance: The accuracy of bowel ultrasound in detecting inflammatory bowel disease

Principal Investigator: Mrs Amanda Hendricks

Department: Radiography - CUT

[Submission Page](#)

APPLICATION APPROVED

Please ensure that you read the whole document

With reference to your application for ethical clearance with the Faculty of Health Sciences, I am pleased to inform you on behalf of the Health Sciences Research Ethics Committee that you have been granted ethical clearance for your project.

Your ethical clearance number, to be used in all correspondence is: UFS-HSD2022/0610/2911

The ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension.

We request that any changes that may take place during the course of your research project be submitted to the HSREC for approval to ensure we are kept up to date with your progress and any ethical implications that may arise. This includes any serious adverse events and/or termination of the study.

A progress report should be submitted within one year of approval, and annually for long term studies. A final report should be submitted at the completion of the study.

Research conducted in any Department of Health facility: Researchers are required to sign and return the HSREC approval letters to the provincial Department of Health where they applied. It is also a requirement for researchers to submit electronic copies of their final research findings, and/or make a presentation of their findings and recommendations at departmental research days when and where indicated.

The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2020); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; International Council for Harmonisation (ICH) Harmonised Guideline, Integrated Addendum to ICH E6(R1), Guideline for Good Clinical Practice (GCP) E6(R2), 2016, SAHPRA Guidelines as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the HSREC of the Faculty of Health Sciences.

The Principal Investigator (PI) bears final responsibility for the RIMS application. In the event of any misconduct or improper activities perpetrated by a third party, the PI will be held vicariously liable. The HSREC will bear no responsibility or liability for any actions of a PI and/or third party or breach of confidentiality caused by the PI and/or third party.

For any questions or concerns, please feel free to contact HSREC Administration: 051-4017794/5 or email EthicsFHS@ufs.ac.za.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours Sincerely



Prof. A. Shemiff

Chairperson: Health Sciences Research Ethics Committee

Health Sciences Research Ethics Committee

Office of the Dean: Health Sciences

T: +27 (0)51 401 7795/7794 | E: ethicsfhs@ufs.ac.za

IRB 00011992; REC 230408-011; IORG 0010096; FWA 00027947

Block D, Dean's Division, Room D104 | P.O. Box/Posbus 339 (Internal Post Box G40) | Bloemfontein 9300 | South Africa

www.ufs.ac.za



Appendix B: Approval letter from Free State Department of Health**health**Department of
Health
FREE STATE PROVINCE

13 October 2022

Ms A Hendicks
Radiography Department
Central University of Technology

Dear Ms A Hendicks

Subject: The Accuracy of Bowel Ultrasound in Detecting Inflammatory Bowel Disease

- Please ensure that you read the whole document, Permission is hereby granted for the above-mentioned research on the following conditions:
- Participation in the study must be voluntary and written consent by each participant must be obtained.
- Serious adverse events to be reported to the Free State department of health and/ or termination of the study.
- Ascertain that your data collection exercise neither interferes with the day-to-day running of [REDACTED] Hospital nor the performance of duties by the respondents or health care workers.
- The DOH expects that the researcher will be the responsible data manager according to the POPI Act. The responsibility thus lies with the researcher to ensure that the processing of all participants' personal information and research data is lawful according to the stipulations of the POPI Act (Protection of Personal Information Act 4 of 2013).
- Confidentiality of information will be ensured and please do not obtain information regarding the identity of the participants.
- Department of Health to be fully indemnified from any contravention of the POPI Act as you conduct this study.
- Research results and a complete report should be made available to the Free State Department of Health on completion of the study (a hard copy plus a soft copy).
- Progress report must be presented not later than one year after approval of the project to the Ethics Committee of the University of Free State and to the Free State Department of Health.
- Any amendments, extensions or other modifications to the protocol or investigators must be submitted to the Ethics Committee of the University of Free State and to the Free State Department of Health.
- Conditions stated in your Ethical Approval letter should be adhered to and a final copy of the Ethics Clearance Certificate should be submitted to Sebelatsi@fshealth.gov.za/Gwantshuwa@fshealth.gov.za before you commence with the study
- No financial liability will be placed on the Free State Department of Health.
- Please discuss your study with the Institution Manager on commencement for logistical arrangements.
- Department of Health to be fully indemnified from any harm that participants and staff experience in the study.
- As part of feedback you will be required to present your study findings/results at the Free State Provincial health research day.

Trust you find the above in order.

Kind Regards

MR. MNG MAHLATSI
HEAD: FREE STATE DEPARTMENT OF HEALTH

Date: 13/10/2022

Appendix C: Approval letter from the Research Ethics Committee of the private hospital

RESEARCH OPERATIONS COMMITTEE FINAL APPROVAL OF RESEARCH

Approval number: UNIV-2022-0056

Ms A Hendricks

E mail: hendricksa258@gmail.com

Dear Ms Hendricks

RE: THE ACCURACY OF BOWEL ULTRASOUND IN DETECTING INFLAMMATORY BOWEL DISEASE

The above-mentioned research was reviewed by the Research Operations Committee's delegated members and it is with pleasure that we inform you that your application to conduct this research at private Hospital, has been approved, subject to the following:

- i) Research may now commence with this FINAL APPROVAL from the Committee.
- ii) All information regarding the Company will be treated as legally privileged and confidential.
- iii) The Company's name will not be mentioned without written consent from the Committee.
- iv) All legal requirements regarding patient / participant's rights and confidentiality will be complied with.
- v) All data extracted may only be used in an anonymised, aggregated format and for the purposes of this specific study as specified in the proposal. The data may under no circumstances be used for any other purpose whatsoever.
- vi) The research will be conducted in compliance with the GUIDELINES FOR GOOD CLINICAL PRACTICE IN HUMAN PARTICIPANTS IN SOUTH AFRICA (2016).
- vii) The Company must be furnished with a STATUS REPORT on the progress of the study at least annually on 30th September irrespective of the date of approval from the Committee as well as a FINAL REPORT with reference to intention to publish and probable journals for publication, on completion of the study.
- viii) A copy of the research report will be provided to the Committee once it is finally approved by the relevant primary party or tertiary institution, or once complete or if discontinued for any reason whatsoever prior to the expected completion date.



Appendix D: Permission letter from the HOD (Gastroenterology) to conduct the study

8 Christoffel Du Plessis
Universitas Ridge
Bloemfontein
9301
March 2022

Dr [REDACTED]
Gastroenterology
[REDACTED] Private Hospital
Bloemfontein 9301

Dear Dr [REDACTED]

**RE: REQUEST TO CONDUCT THE RESEARCH STUDY AT THE [REDACTED]
[REDACTED] HOSPITAL IN BLOEMFONTEIN.**

I, hereby request permission to conduct a research study at the abovementioned hospital for a Master's (Ultrasound) Degree at the Central University of Technology. The title of my study is the accuracy of bowel ultrasound in detecting Inflammatory Bowel Disease. The aim of this study is to investigate the accuracy of bowel ultrasound in detecting (IBD). Furthermore, the intent of the study is to provide an accurate imaging modality that will assist in detecting and monitoring IBD and that will assist in image interpretation to ensure an accurate diagnosis. It will also provide a standardised protocol/guidelines for IBD that will help with the training of ultrasound operators.

The participants' anonymity will be strictly adhered to and kept confidential throughout the study. The study will commence in August 2022 and data will be collected at a convenient date and time suitable for the hospital. Adult patients with suspected signs or clinically diagnosed with IBD will be included in the study. These patients will also need to have had laboratory tests, a colonoscopy with biopsy and bowel ultrasound (BUS).

A prospective, explorative, quantitative study method will be used to achieve the aim of this study. A skilled sonographer will perform a transabdominal ultrasound scan

Of the bowel on each patient. The radiologist will write the final ultrasound report. The final ultrasound report will be compared with the final diagnosis/histology report. Written informed permission (consent) will be requested from all patients. Local ethics committee approval will be obtained before the study is conducted.

The expected result for this study to support that BUS is an accurate non-invasive imaging technique to detect and monitor IBD and that it can be used with confidence as the first method of investigation to detect IBD.

Please find a copy of the research proposal that has been submitted to the Medical Ethics Committee at the University of Free State in Bloemfontein for approval. The research study will be published in an applicable journal and presented at the annual research day at the Central University of Technology, Free State (CUT) Bloemfontein.

I trust that you will consider the above request favourably.



Amanda Hendricks

.....
Contact details: Cell: 0822245449

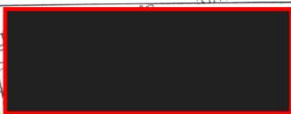
E-mail address: Hendricksa258@gmail.com

Kindly indicate your provisional approval and support of the study based on final ethics approval from the ethics committee of HSREC, UFS, or not, by marking the appropriate box below:

☒ **APPROVED**

☐ **NOT APPROVED**

Recommendations/ Comments if applicable:

.....
C 

.....
Signature Dr 

Gastroenterology  Private Hospital

Date 11/7/2022

Appendix E: Permission letter from HOD (radiology department) to conduct the study**APPENDIX F: REQUEST TO CONDUCT THE RESEARCH STUDY**

8 Christoffel Du Plessis
Universitas Ridge
Bloemfontein
9301
March 2022

Prof [REDACTED]
Head of Department [REDACTED]
[REDACTED] Hospital
Bloemfontein 9301

Dear Prof [REDACTED],

**RE: REQUEST TO CONDUCT THE RESEARCH STUDY AT [REDACTED]
[REDACTED] HOSPITAL IN BLOEMFONTEIN**

I hereby request permission to conduct a research study at the abovementioned hospital for a Master's (Ultrasound) Degree at the Central University of Technology. The title of my study is the accuracy of bowel ultrasound in detecting Inflammatory Bowel Disease. The aim of this study is to investigate the accuracy of bowel ultrasound in detecting (IBD). Furthermore, the intent of the study is to provide an accurate imaging modality that will assist in detecting and monitoring IBD and that will assist in image interpretation to ensure an accurate diagnosis. It will also provide a standardised protocol/guidelines for IBD that will help with the training of ultrasound operators.

The participants' anonymity will be strictly adhered to and kept confidential throughout the study. The study will commence in August 2022 and data will be collected at a convenient date and time suitable for the hospital. Adult patients with suspected signs or clinically diagnosed with IBD will be included in the study. These patients will also need laboratory tests, a colonoscopy with biopsy, and a bowel ultrasound (BUS).

A prospective, explorative, quantitative study method will be used to achieve the aim of this study. A skilled sonographer will perform a transabdominal ultrasound scan of the bowel on each patient. The radiologist will write the final ultrasound report. The final ultrasound report will be compared with the final diagnosis/histology report. Written informed permission (consent) will be requested from all patients. Local ethics committee approval will be obtained before the study is conducted.

The expected result for this study is to support that BUS is an accurate non-invasive imaging technique to detect and monitor IBD and that it can be used with confidence as the first method of investigation to detect IBD.

Please find a copy of the research proposal that will be submitted to the Medical Ethics Committee at the University of Free State in Bloemfontein for approval. The research study will be published in an applicable journal and presented at the annual research day at the Central University of Technology, Free State (CUT) Bloemfontein.

I trust that you will consider the above request favourably.



Amanda Hendricks
Contact details: Cell: 0822245449
E-mail address: Hendricksa258@gmail.com

Kindly indicate your provisional approval and support of the study based on final ethics approval from the ethics committee of HSREC, UFS, or not, by marking the appropriate box below:

APPROVED

NOT APPROVED

Recommendations/ Comments If a

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M

De

Signature of HOD,  Hospital

Date

05 July 2022

Appendix F: Permission letter from gastroenterologists of the private hospital to conduct the study

8 Christoffel Du Plessis
Universitas Ridge
Bloemfontein
9301
March 2022

Dr [REDACTED]
Medical Gastroenterology
Department of [REDACTED]
Faculty: [REDACTED]
PO. Box 339
Bloemfontein
9300

Dear Dr [REDACTED]

**RE: REQUEST TO CONDUCT THE RESEARCH STUDY AT THE [REDACTED]
[REDACTED] HOSPITAL IN BLOEMFONTEIN.**

I, hereby request permission to conduct a research study at the abovementioned hospital for a Master's (Ultrasound) Degree at the Central University of Technology. The title of my study is the accuracy of bowel ultrasound in detecting Inflammatory Bowel Disease. The aim of this study is to investigate the accuracy of bowel ultrasound in detecting (IBD). Furthermore, the intent of the study is to provide an accurate imaging modality that will assist in detecting and monitoring IBD and that will assist in image interpretation to ensure accurate diagnosis. It will also provide a standardised protocol/guidelines for IBD that will help with the training of ultrasound operators.

The participants' anonymity will be strictly adhered to and kept confidential throughout the study. The study will commence in August 2022 and data collected at a convenient date and time suitable for the hospital. Adult patients with suspected signs or clinically diagnosed with IBD will be included in the study. These patients

will also need to have had laboratory tests, a colonoscopy with biopsy, and bowel ultrasound (BUS).

A prospective, explorative, quantitative study method will be used to achieve the aim of this study. A transabdominal ultrasound scan of the bowel will be performed on each patient by a skilled sonographer. The radiologist will write the final ultrasound report. The final ultrasound report will be compared with the final diagnosis/histology report. Written informed permission (consent) will be requested from all patients. Local ethics committee approval will be obtained before the study is conducted.

The expected result for this study is to support that BUS is an accurate non-invasive imaging technique to detect and monitor IBD and that it can be used with confidence as the first method of investigation to detect IBD.

Please find a copy of the research proposal that has been submitted to the Medical Ethics Committee at the University of Free State in Bloemfontein for approval. The research study will be published in an applicable journal and presented at the annual research day at the Central University of Technology, Free State (CUT) Bloemfontein.

I trust that you will consider the above request favourably.



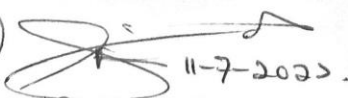
Amanda Hendricks

.....
Contact details: Cell: 0822245449

E-mail address: Hendricksa258@gmail.com

Kindly indicate your provisional approval and support of the study based on final ethics approval from the ethics committee of HSREC, UFS, or not, by marking the appropriate box below:

APPROVED



NOT APPROVED

Recommendations/ Comments if applicable:

Signature Dr

Gastroenterology

Private Hospital

11-7-2022.

Date

Appendix G: Informed consent form**CONSENT TO PARTICIPATE IN RESEARCH STUDY**

Consent form based on Divers Alert Network (2021)

TITLE: The accuracy of bowel ultrasound in detecting inflammatory bowel disease**SUMMARY**

The aim of this study is to investigate the accuracy of ultrasound in detecting inflammatory bowel disease in patients who are suspected or clinically diagnosed with inflammatory bowel disease.

Participants in this study will undergo an abdominal ultrasound scan of the bowel. Your participation is complete once all ultrasound scans have been performed.

Ultrasound is a diagnostic test that uses sound waves and a computer to produce images of internal body parts. Ultrasound is a safe and non-invasive procedure compared to other diagnostic imaging tests. However, you may experience slight discomfort during continuous exposure to ultrasound due to the pressure of the transducer/probe applied to the ribs.

INTRODUCTION

You are invited to volunteer to collect ultrasound images of the bowel segments for this research study. To decide whether you wish to be in the study, you will need to know about the benefits or risks you may experience due to your participation. It is important that you understand this information to make an informed choice about being a part of this research study. You will be given a copy of this consent form. You can ask any questions you might have at any time.

PURPOSE OF THE STUDY

The purpose of this study is to collect ultrasound evidence /images of the inflamed bowel segments to determine the accuracy of ultrasound as a non-invasive imaging test in detecting inflammatory bowel disease (specifically Crohn's disease and ulcerative colitis (UC)). Bowel ultrasound is most commonly used to identify complications of Crohn's disease and UC. This study seeks to clarify whether bowel ultrasound can be used as the first line of investigation to detect Crohn's disease and UC in patients clinically diagnosed with inflammatory bowel disease.

BACKGROUND

Inflammatory bowel disease (IBD) is a chronic disorder that causes chronic inflammation in the gastrointestinal tract. IBD can affect either or both the small and large bowel; the most common types are Crohn's disease and ulcerative colitis (UC). Accurate and early diagnosis of IBD is crucial for patients suffering from clinical symptoms of IBD. This is to speed up treatment and limit the risk of complications of this disease. Bowel ultrasound can play a significant role as the primary or first-line imaging tool to diagnose or detect IBD. Therefore, the aim of this prospective study is to determine the accuracy of BUS as the primary- or first-line imaging tool in detecting IBD in patients with suspected or clinically diagnosed IBD (Crohn's disease and UC) at the [redacted to ensure anonymity] in Bloemfontein in the Free State.

HOW THE STUDY WORKS

Patients must be 18 years of age or older with suspected symptoms or clinically diagnosed with IBD. This includes patients from the gastroenterology clinic at [redacted to ensure anonymity] Hospital and [redacted to ensure anonymity] Hospital. All genders are eligible to participate. Patients will be asked to read and sign the consent form and will have the opportunity to ask any relevant questions. An abdominal ultrasound scan of the bowel will be performed on each patient by an experienced sonographer at the radiology department at [redacted to ensure anonymity] Hospital.

RISKS TO YOU

Confidentiality

The researcher will abide by the privacy regulations that provide safeguards for privacy and secured and authorised access to data. Except for your signed informed consent, the records of your participation do not contain your identification data and cannot be traced back to you. You will receive a random ID (identity) number, and all your ultrasound findings will be labelled with that ID number. The link between your name and that number will be destroyed immediately after the study. No data will be recorded that could identify you. The electronic copy of your informed consent will be kept on a protected server for ten years. Your name will not be used in journal articles or at meetings when the results of this study are reported.

Ultrasound examination:

Some individuals may experience slight discomfort during continuous exposure of ultrasound due to the pressure applied with the transducer /probe to their ribs. The spectrum of ultrasound used in this

study is not expected to induce biological or medical damage or expose the participant any additional risk.

Unforeseen risks:

The research procedures may involve a risk that is currently unforeseeable. However, any new risks that we may learn about during the course of your participation will be shared with you.

BENEFITS TO YOU

There are no direct benefits to you participating in the study. However, your participation will assist in developing a safe, non-invasive first-line imaging test to accurately diagnose or detect IBD.

WITHDRAWALS

You can withdraw from this study at any time and your data will be removed from the study.

COMPENSATION/COSTS

Participants will not receive any compensation (money) for this study. Participation in the study is voluntary.

YOUR RIGHTS

It is necessary that you read and understand several general principles that apply to everyone who takes part in this study:

1. Taking part in this study is entirely voluntary. You may choose not to be in the study, or if you agree to be in the study, you may withdraw from the study at any time. If you withdraw from the study, no new data about you will be collected for study purposes. If you do decide to withdraw, we ask that you contact your doctor at the gastroenterology clinic, who will then contact the research team; at that time, we will ask your permission to continue using your information that has already been collected as part of the study before your withdrawal.
2. There will be no charge (cost) for taking part in this study.
3. Research records are maintained according to confidentiality requirements.

QUESTIONS

Should you have any questions about this research, you are urged to contact the principal researcher, Ms Amanda Hendricks (hendricksa258@gmail.com)

AUTHORISATION

The purpose of this study, procedures to be followed, risks and benefits have been explained. I have been allowed to ask questions, and my questions have been answered to my satisfaction. I have been told whom to contact if I have additional questions. I have read this consent form and agree to be in this study, understanding that I may withdraw at any time. I have been told that I will be given a signed copy of this consent form.

Signature of participant_____ Date_____

Printed name of participant_____

Person obtaining consent_____ Date_____

AFRIKAANS: INGELIGTE TOESTEMMINGVORM**TOESTEMMING OM AAN NAVORSINGSSTUDIE DEEL TE NEEM**

TITEL: Die akkuraatheid van dermat-ultraklank in die opsporing van inflammatoriese dermsiekte

OPSOMMING

Die doel van hierdie studie is om die akkuraatheid van ultraklank te bepaal in die opsporing van inflammatoriese dermsiekte by pasiënte wat vermoedelik of klinies gediagnoseer word met inflammatoriese dermsiekte.

Deelnemers aan hierdie studie sal 'n abdominale ultraklankskandering/ondersoek van die derm ondergaan. U deelname is voltooi sodra alle ultraklankskanderings/ondersoeke uitgevoer is.

Ultraklank is 'n diagnostiese toets wat klankgolwe en 'n rekenaar gebruik om beelde van interne liggaamsdele te produseer. Ultraklank is 'n veilige en nie-indringende prosedure in vergelyking met ander diagnostiese beeldingstoetse. U kan egter effense ongemak ervaar tydens aanhoudende blootstelling aan ultraklank as gevolg van die druk van die klankkop wat op die ribbes toegepas word.

INLEIDING

U word hiermee uitgenooi om vrywilliglik deel te neem aan hierdie navorsings studie, waar ultraklankbeelde van geaffekteerde/onsteekte dermsegmente vermoedelik as gevolg van inflammatoriese dermsiekte te versamel.

Voordat u vrywilliglik deelneem in hierdie navorsings studie is dit belangrik dat u die voordele en moontlike risiko's wat u as gevolg van deelname mag ervaar verstaan om sodoende 'n ingeligte keuse te maak. U sal 'n afskrif van hierdie toestemmingsvorm ontvang. U is welkom om enige tyd vrae te vra indien daar enige onduidelikheid is omtrent die studie of u deelname.

DOEL VAN DIE STUDIE

Die doel van hierdie studie is om die akkuraatheid van ultraklank te bepaal as 'n nie-indringende beeldingstoets/beeldings modaliteit in die opsporing van inflammatoriese dermsiekte (spesifiek Crohn se siekte en ulseratiewe kolitis) by pasiënte met verdagte simptome of klinies gediagnoseer is met inflammatoriese dermsiekte by die [redacted to ensure anonymity] Hospitaal in Bloemfontein.

Ultraklank word die meestal gebruik om die komplikasies van Crohn se siekte en ulseratiewe kolitis uit te skakel of te bevestig. Hierdie studie poog om te bevestig of dermat-ultraklank gebruik kan word

as die primêre diagnostiese beeldingstoets van keuse inflammatiese dermsiekte op te spoor by pasiënte met verdagte simptome of klinies gediagnoseer is met inflammatiese dermsiekte.

AGTERGROND

Inflammatiese dermsiekte (IDS) is 'n afwyking wat kroniese inflammasie in die spysverteringskanaal veroorsaak. IDS kan een of beide die dunderm en dikderm affekteer. Die mees algemene tipes is, Crohn se siekte en ulseratiewe kolitis. Akkurate en vroeë diagnose van IDS is noodsaaklik vir pasiënte wat aan kliniese simptome van IDS ly. Dit is om behandeling te bespoedig en die risiko van komplikasies van hierdie siekte te beperk. Derm-ultraklank kan 'n beduidende rol speel as die primêre of eerstelyn diagnostiese beeldingstoets/beeldings modaliteit om IDS te diagnoseer of op te spoor.

HOE DIE STUDIE WERK

Deelnemers moet 18 jaar of ouer wees met vermoedelike simptome IDS of klinies gediagnoseer met IDS. Dit sluit pasiënte van die gastroënterologie-kliniek by [redacted to ensure anonymity] Hospitaal en [redacted to ensure anonymity] Hospitaal in. Alle geslagte kom in aanmerking om deel te neem. Pasiënte sal gevra word om die toestemmingsvorm te lees en te onderteken en sal die geleentheid kry om enige relevante vrae te vra.

'n Abdominale ultraklankondersoek van die derm sal op elke deelnemer uitgevoer word deur 'n ervare sonograaf by die radiologie-afdeling by [redacted to ensure anonymity] Hospitaal.

RISIKO'S VIR JOU

Vertroulikheid

Die navorser sal gehoor gee aan die privaatheidsregulasies wat voorsiening maak vir privaatheid en veilige en gemagtigde toegang tot data. Behalwe vir u getekende ingeligte toestemming, bevat die rekords van u deelname nie u identifikasiedata nie en kan dus nie na u teruggespoor word nie. U sal 'n ewekansige ID-nommer (identiteitsnommer) ontvang, en al u ultraklankbevindings sal met daardie ID-nommer gemerk word. Die skakel tussen u naam en daardie nommer sal onmiddellik na die studie vernietig word. Geen data sal aangeteken word wat u kan identifiseer nie. Die elektroniese kopie van u ingeligte toestemming sal vir tien jaar op 'n beskermde databasis gehou word. U naam sal nie in joernaalartikels of by vergaderings gebruik word wanneer die resultate van hierdie studie gerapporteer word nie.

Ultraklank ondersoek:

Sommige individue kan effense ongemak ervaar tydens deurlopende blootstelling van ultraklankondersoek as gevolg van die druk wat met die klankkop op hul ribbes toegepas word. Daar word nie verwag dat die spektrum van ultraklank wat in hierdie studie gebruik word, biologiese of mediese skade sal veroorsaak of die deelnemer aan enige bykomende risiko sal blootstel.

Onvoorsiene risiko's:

Die navorsingsprosedures kan 'n risiko inhou wat tans onvoorsienbaar is. Enige nuwe risiko's waaroor ons in die loop van jou deelname kan leer, sal egter met u gedeel word.

VOORDELE VIR JOU

Daar is geen direkte voordele vir u om aan die studie deel te neem nie. U deelname sal egter help met die ontwikkeling van 'n veilige, nie-indringende primêre beeldingstoets/ eerste-lyn beeldingstoets om IDS akkuraat te diagnoseer of op te spoor.

ONTTREKKING

U kan enige tyd aan hierdie studie onttrek en u data sal uit die studie verwyder word.

VERGOEDING/KOSTE

Deelnemers sal geen vergoeding (geld) vir hierdie studie ontvang nie. Deelname aan die studie is vrywillig.

JOU REGTE

Dit is nodig dat u die verskeie algemene beginsels lees en verstaan wat van toepassing is op almal wat aan hierdie studie deelneem:

1. Deelname aan hierdie studie is heeltemal vrywillig. U kan kies om nie in die studie te wees nie, of as u instem om in die studie te wees, kan u enige tyd aan die studie onttrek. Indien u aan die studie onttrek, sal geen nuwe data oor u vir studiedoeleindes ingesamel word nie. Indien u wel besluit om te onttrek, vra ons dat u u dokter by die gastroënterologiese kliniek kontak, wat dan die navorsingspan sal kontak; op daardie tydstip sal ons u toestemming vra om voort te gaan om u inligting te gebruik wat reeds ingesamel is as deel van die studie voor u onttrekking.
2. Daar sal geen koste (koste) wees om aan hierdie studie deel te neem nie.
3. Navorsingsrekords word volgens vertroulikheidsvereistes bygehou.

VRAE

Indien u enige vrae oor hierdie navorsing het, word u versoek om die hoofnavorser mev Amanda Hendricks (hendricksa258@gmail.com) te kontak.

MAGTIGING

Die doel van hierdie studie, prosedures wat gevolg moet word, risiko's en voordele is verduidelik. Ek is toegelaat om vrae te vra, en my vrae is tot my bevrediging beantwoord. Ek is aangesê wie om te kontak as ek bykomende vrae het. Ek het hierdie toestemmingsvorm gelees en stem in om in hierdie studie te wees, met begrip dat ek enige tyd kan onttrek. Ek is meegedeel dat ek 'n getekende afskrif van hierdie toestemmingsvorm sal ontvang.

Handtekening van deelnemer _____ Datum _____

Gedrukte naam van deelnemer _____

Persoon wat toestemming verkry _____ Datum _____

SESOTHO: FOROMO EA TUMELO E TSEBISANG**TUMELLO EA HO NKA KAROLO BOITHUTONG BA LIPATLISISO**

Fomo ya temello

SEHLOOHO: Ho nepahala ha hlahlobo ya ultrasound ya mala ho lemoha lefu la ho ruhuha ha mala

KAKARETSO

Sepheo sa phuputso ena ke ho fumana bonnete ba hlahlobo ya ultrasound ya mala mabapi le ho lemoha lefu la mala a ho ruhuha ho bakudi ba belaelwang kapa ba fumanwang ba ena le lefu la ho ruhuha ha mala.

Bankakarolo thutong ena ba tla hlahlojwa ka mpeng ka ultrasound ya mala. Ho nka karolo ha hao ho tlabe ho fedile hang ha dihlahlobo tsohle tsa ultrasound ya mala di entswe.

Ultrasound ke teko ya hlahlobo e sebedisang maqhubu a modumo le khomphutha ho hlalisa ditshwantsho tsa ditho tse ka hare tsa mmele. Ultrasound ke mokgwa o sireletsehileng le o sa hlaseleng ditho tsa mmele ha o bapiswa le diteko tse ding tsa ho hlahloba ka ditshwantsho. Leha ho le jwalo, o ka nna wa ikutlwa o sa phutholoha hanyenyane nakong ya ho pepeseha ho sa kgaotseng ho ultrasound ka lebaka la kgatello ya transducer / probe e sebediswang dikgopong.

SELELEKELA

O memelwa ho ithaopela ho bokella ditshwantsho tsa ultrasound tsa dikarolo tsa mala bakeng sa phuputso ena ya dipatlosiso.

Molemong wa ho etsa qeto hore na oka batla hoba karalo ka thuto ena, o hloka ho tseba ka melemo kapa dikotsi tseo o ka bang le tsona ka lebaka la ho nka karolo ha hao. Ho bohlokwa hore o utlwisise dintlha tsena ho etsa kgetho e nang le tsebo mabapi le ho ba karolo ya phuputso ena. O tla fuwa pampitshana ya foromo ena ya tumello. O ka botsa dipotso leha e le dife tseo o ka bang le tsona ka nako leha e le efe.

MORERO WA THUTO

Sepheo sa phuputso ena ke ho bokella bopaki ba ultrasound / ditshwantsho tsa dikarolo tsa mala a ruhuhileng ho fumana bonnete ba ultrasound e le teko ya ditshwantso e sa hlaseleng ho lemoheng lefu la ho ruhuha ha mala (haholo-holo Crohn's disease le ulcerative colitis (UC). ultrasound e atisa ho sebeliswa ho kgetholla mathata a Crohn's disease le UC. Phuputso ena e batla ho hlakisa hore na ultrasound ya mala e ka sebeliswa e le mokgwa wa pele wa dipatlisiso ho lemoha Crohn's disease le UC ho bakudi ba fumanwang ba ena le lefu la ho ruhuha ha mala.

BOKAMORAO

Lefu la ho ruhua ha mala (IBD) ke lefu le sa foleng le bakang ho ruhua ho sa foleng ha mothapo wa mala. IBD e ka ama mala a manyane kapa a maholo kapa ka bobedi ba ona; mefuta e tlwaelehileng haholo ke Crohn's disease le ulcerative colitis (UC). Hlahlobo e nepahetseng ya potlako ya IBD ke ya bohlokoa ho bakudi ba nang le matshwao a IBD. Sena ke ho potlakisa phekolo le ho fokotsa kotsi ya mathata a lefu lena. Ultrasound ya mala e ka bapala karolo ya bohlokwa e le sesebediswa sa pele sa ho etsa ditshwantsho ho hlahloba kapa ho lemoha IBD. Ka hoo, sepheo sa phuputso ena ke ho fumana bonnete ba BUS e le sesebediswa sa pele sa ho nka ditshwantsho ho bona IBD ho bakudi ba belaelwang kapa ba fumanwang bana le IBD (Crohn's disease le UC) sepetleleng sa se Bloemfontein Free State.

KAMOO THUTO E SEBETSANG KATENG

Bakudi ba tlameha ho ba dilemo tse 18 kapa ho feta, ba balaellwang ka matshwao kapa ba fumanwang ba ena le IBD. Sena se kenyelletsa bakudi ba tleliniki ya lefu la Gastroenterology Sepetleleng sa [redacted to ensure anonymity] le Sepetlele sa [redacted to ensure anonymity]. Bong bohle ba ka nka karolo. Bakudi ba tla kopuwa ho bala le ho saena foromo ya tumello mme ba tla ba le monyetla wa ho botsa dipotso leha e le dife tse amehang.

Hlahlobo ya ultrasound ya mala e tla etswa ho mokudi e mong le e mong ke setsebi se nang le phihlelo lefapheng la radiology Sepetlele sa [redacted to ensure anonymity].

DIKOTSI HO WENA

Lekunutu:

Mofuputsi o tla latela melawana ya lekunutu e fanang ka tshireletso ya lekunutu le phihlelo e sireleditsweng le e dumelletsoeng ho direkoto. Ntle le tumello ya hao e saennweng, direkoto tsa ho nka karolo ha hao, ha dina dintlha tsa boitsebiso mme di ke ke tsa salwa morao ho wena. O tla fumana nomoro ya ID (boitsibiso) eo e seng ya hao, mme diphuputso tsohle tsa hao tsa ultrasound di tla ngolwa ka nomoro eo ya ID. Kgokahano dipakeng tsa lebitso la hao le nomoro eo e tla senngwa hang kamora thuto. Ha ho na direkoto tse tla o khethollang. Pampitshana ya elektroniki e nang le tumellano ya hao e saennweng e tla bolokwa dilemo tse leshome ho server e sireleditsweng haholo. Lebitso la hao le ke ke la sebeliswa ho dingolwa tsa dikoranta kapa dikopanong ha diphetho tsa boithuto bona di tlalehwa

Hlahlobo ya Ultrasound:

Batho ba bang ba ka nna ba ikutlwa ba sa phutholoha ha ba ntse ba pepesehela ultrasound ka lebaka la kगतello e sebeliswang ke transducer / probe dikhopong tsa bona. Bongata ba ultrasound bo sebelisitsweng thutong ena ha boa lebellwa ho baka tshenyo ya baeloji kapa ya bongaka kapa ho pepesa monkakarolo kotsi efe kapa efe e eketsehileng,

Dikotsi tse sa lebellwang:

Mekgwa ya dipatlisiso e ka nna ya kenyelletsa kotsi e sa lebelloang. Leha ho le jwalo, dikotsi dife kapa dife tse ntjha tseo re ka ithutang tsona nakong eo o nkang karolo di tla arolelanwa le wena.

MELEMO HO WENA

Ha ho melemo e tobileng ho wena ho nka karolo thutong. Leha ho le jwalo, ho nka karolo ha hao ho tla thusa ho etsa hlahlobo e bolokehileng, e sa senyeng ya pele ya ho hlahloba kapa ho lemoha IBD.

HO IKGULA

O ka ikgula thutong ena ka nako efe kapa efe mme rekoto ya hao e tla hlakolwa phuputsong ena.

MATSHIDISO

Baithaupi ba ke ke ba fumana matshidiso (tjhelete) karolong ena ya thuto.

DITOKELO TSA HAO

Ho a hlokahala hore o bale le ho utlwisisa melawana e mengata e akaretsang e sebetsang ho bohle ba nkang karolo thutong ena:

1. Ho nka karolo thutong ena ke boithaopo ka ho felletseng. O ka ikgethela ho se be teng phuputsong ena, kapa ha o dumela ho ba thutong, o ka ikgula thutong ena neng kapa neng. Ha o ikgula phuputsong, ha ho rekoto e ntjha ka wena e tla bokellwa bakeng sa merero ya boithuto. Haeba o etsa qeto ya ho ikgula, re u kopa hore u ikopanye le ngaka ya hao tleliniking ya gastroenterology, e tla ikopanya le sehlopha sa dipatlisiso. Ka nako eo, re tla kopa tumello ya hao ya ho tswelapele ho sebedisa tlhahiso-leseding ya hao e seng e bokellwetswe e le karolo ya phuputso pele o ikgula.

2. Ho ke ke ha ba le tefo (ditshenyehelo) bakeng sa ho nka karolo phuputsong ena.

3. Direkoto tsa dipatlisiso di bolokwa ho latela ditlhoko tsa lekunutu.

DIPOTSO

Haeba ona le dipotso mabapi le dipatlisiso tse, o kgothaletswa ho ikopanya le mofuputsi ya ka sehloohong Mofumahali Amanda Hendricks (hendricksa258@gmail.com)

TUMELLO

Maikemisetso a thuto-patlisiso ena, mekgwa e tshwanetseng ho latelwa, dikotsi le melemo e hlalositswe. Ke dumeletswe ho botsa dipotso, mme dipotso tsa ka di arabilwe ka tsela e nkgotsofatsang. Ke boleletswe hore na ke ikopanye le mang haeba ke na le dipotso tse ding. Ke badile foromo ena ya tumellano mme ke dumela ho ba thutong ena, ke utlwisisa hore nka ikgula neng kapa neng. Ke boleletswe hore ke tla fuwa pampitshana e saennweng ya foromo ena ya tumellano.

Tshaeno ya monkakarolo _____ Letsatsi _____

Lebitso le hatisitsweng la monkakarolo _____

Motho ya fumanang tumellano _____ Letsatsi _____

Appendix H: Letter from statistician

Maryn Viljoen
Statistics Consulting Services

082 823 5731
maryn.viljoen1@gmail.com

Protocol & research methodology consultation | Ethical consultation | Database construction & capturing of data
Analysing data using statistical software packages (SAS Version 9.2) | Statistics consultation services to analyse and interpret data
Conveys results with statistical tables & figures where needed

The Chairperson: Health Sciences Research Ethics Committee (HSREC)
For Attention: Mrs. M.G.E. Marais
Block D, Room 104
Francois Retief Building
Faculty of Health Sciences
University of the Free State

7 February 2022

Title: "The diagnostic accuracy of bowel ultrasound in detecting
inflammatory bowel disease."

Researcher: Amanda Hendricks
Faculty of Health and Environmental Sciences
Department of Clinical Science: Programme Radiography
Central University of Technology, Free State
Bloemfontein

I have seen and read through this protocol. I gave input and recommendations
and will be the biostatistician responsible for the analysis of the data.

Maryn Viljoen
M.Sc. Risk Analysis (UFS)
maryn.viljoen1@gmail.com
082 82 35 731

Appendix I: Letter from the language editor

Declaration

25 May 2024

PO Box 4

Otjiwarongo

Namibia

+264 813359120

hettie.human@gmail.com

Dissertation: The accuracy of bowel ultrasound in detecting inflammatory bowel
disease

Student: Amanda Hendricks

I confirm that I edited and formatted the dissertation, checked the references, and recommended changes to the text.



MA Language Practice



Hettie Human
WRITER | EDITOR | TRANSLATOR | INTERPRETER



Appendix J: Turnitin report

The accuracy of bowel ultrasound in detecting inflammatory bowel disease

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