The use of computed tomography for the detection of gastrointestinal injury in patients with penetrating torso trauma: a central South African experience.

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Submitted in fulfilment of the requirements in respect of the Master's Degree MMed in the Department of Clinical Imaging Sciences in the Faculty of Health Sciences at the University of the Free State.

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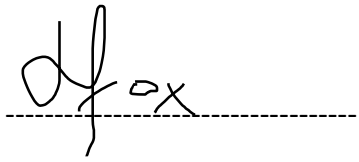
Author declaration

I, Lilanie Biddulph, declare that the coursework Master's Degree mini-dissertation that I herewith submit in a publishable manuscript format for the Master's Degree MMed Diagnostic Radiology, at the University of the Free State is my independent work and that I have not previously submitted it for a qualification at another institution of higher education.



Authors' contribution

Lilanie Biddulph was the principal investigator who planned and executed the study, after obtaining ethical approval from the necessary ethical boards, and subsequently wrote the final manuscript after statistical analysis of the obtained data was performed.

Prof G Joubert provided input on the data sheet, did statistical analysis of the data obtained, and critically evaluated the manuscript and approved the final version.

Dr. J Janse van Rensburg was the study leader and critically evaluated the manuscript and approved the final version.

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Abstract:

Background

There is a consensus that selective nonoperative management is the strategy of choice for patients with penetrating torso trauma that are haemodynamically stable and do not have generalised peritonitis. Amongst two prominent trauma associations Computed Tomography is either considered part of the management strategy or given as an option depending on available resources. However, during a systematic review conducted in 2018 CT was found to fall short in the evaluation of possible gastrointestinal injury with a prevalence of 8,7% of false negative CT scans. Given that in our clinical setting there is a high incidence of penetrating torso trauma it is of value to review our local accuracy in diagnosing penetrating gastrointestinal injury using CT and to determine which direct and/or indirect signs are of greatest value for doing so.

Objectives

Determining the local accuracy for identifying gastrointestinal injury on CT and reviewing the local sensitivity and specificity of some described signs for the detection of GIT injury.

Method

CT scans that included the torso and clinical records were reviewed for all patients with penetrating torso trauma that presented to Pelonomi Academic Hospital trauma centre from 18 December 2017 until 18 June 2019 and received a CT scan prior to surgery or discharge after a minimum of 24 hours serial clinical examination. A select number of direct and indirect CT signs for gastrointestinal injury were documented and compared to surgically confirmed GIT injury or presumed negative for GIT injury if the patient was discharged after 24 hours serial clinical examinations without clinical features suggestive of GIT injury.

Results

Of the 114 cases that formed part of the study 44 (38,6%) had surgically proven GIT injury. GIT wall thickening and intra peritoneal free fluid at a site distant to the tract in the absence of solid organ injury had the greatest sensitivity and specificity of the signs evaluated each with a sensitivity of 77,3% and 73,5% and a specificity of 82,9 and 89,7% respectively. In spite of the overall high local sensitivity of 93,2% for identifying GIT injury based on CT findings, there was a prevalence of 6,8% of false negative cases.

Conclusion

CT may be used as an adjunct in the evaluation of patients with penetrating torso trauma with clinical evaluation as the mainstay of management as CT cannot safely exclude GIT injury.

Keywords:
Penetrating torso trauma, Gastrointestinal injury, Computed Tomography, Serial clinical examinations, Selective non operative management.

List of tables:

Chapter 1:

Literature review

Mandatory explorative laparotomy (LAP) for penetrating torso trauma emerged as a management protocol in the era of the world wars when the assumption was that penetrating wounds had a strong association with underlying visceral injuries and that a delay in surgical management would be associated with higher complication rates and therefore a higher rate of morbidity and mortality.[1] By the 1960's this trend of mandatory LAP for all penetrating torso trauma was shifting to an entity known as selective nonoperative management (SNOM) in haemodynamically stable patients with anterior abdominal stab wounds. This approach followed the realisation that routine LAP for all patients with penetrating torso trauma led to nontherapeutic laparotomy rates as high as 35-53%, exposing these patients to unnecessary surgical and postoperative risk.[2,3] Due to the success of well applied SNOM in reducing patient hospital stay duration, especially of those patients who would have had non-therapeutic laparotomies (N- LAP) with all their associated possible complications and increased costs, SNOM has branched out and is now being applied to stab wounds (SW) in different regions of the torso and even to penetrating injuries secondary to gunshot wounds (GSW).[2-4]

There is currently a consensus amongst experts that patients with penetrating torso trauma that are haemodynamically unstable and/or have generalised peritonitis should progress to LAP without delay.[3] For the rest of the patients both the Eastern Association for the Surgery of Trauma (EAST) and the Western Trauma Association (WTA) advocate SNOM.[3] Where these two associations differ is in their work up for patients who qualify for SNOM. EAST recommends serial clinical examination (SCE) and computed tomography (CT) of the abdomen and pelvis whereas the WTA guidelines advocate the use of one of, or a combination of, SCE; local wound exploration; or CT based on available resources and the provider preference. [3]

There is however no universally acceptable guideline with regard to how long the patients being managed non-operatively should be monitored and managed in hospital with SCE prior to safe discharge of the patient. In the literature it has been noted that the majority of cases of patients with penetrating GIT injury requiring surgical repair become clinically apparent within 12-24 hours, with some authors saying within 4-6 hours, and hence various studies have used a cut-off of between 24 and 48 hours of SNOM prior to discharging a patient that has not developed clinical features suggestive of underlying intra-abdominal injury in need of surgical intervention.[3-6] The EAST management protocol of patients with penetrating torso trauma recommends 24 hour of reliable SCE prior to discharging a patient that has remained clinically stable without developing abdominal tenderness.[3]

Overall CT in the setting of penetrating trauma has been shown to have a sensitivity of 97% and a specificity of 98% for detecting peritoneal violation.[1] The exclusion of peritoneal

violation saves costs and manpower as these patients may then be safely discharged without the need for admission and SCE.[6] Research supports that CT is also useful in the detection of vascular injuries that may be amenable to angioembolisation, or that may require open surgical intervention, and further for the evaluation and grading of solid organ injury.[1] Grading solid organ injury based on the American Association for the Surgery of Trauma (AAST) injury scoring scales, in conjunction with the patient's clinical condition, assists the clinician in determining which patients with solid organ injury are most likely to be managed successfully with SNOM and which patients might require intervention with angioembolisation or LAP.[1]

Locally CT is used in conjunction with SCE for patients presenting with penetrating torso trauma, based on the clinical suspicion of intra-abdominal injury and the preference of the managing clinician. Due to finite resources not all patients who clinically require explorative laparotomy have immediate access to theatre and in some of these cases the patients then receive CT evaluation prior to surgery. In terms of bowel injury CT was found to have sensitivities ranging from 67% to 100% and specificities ranging from 80% to 97% with an identifiable wound tract leading to the bowel being the most sensitive sign.[1,7] However in a systematic review conducted by Baron and colleagues in 2018 they found that there was a prevalence of 8,7% of false negative CT scans in patients who actually required LAP and that approximately 40% of these patients had hollow viscus injury.[3] Given this and that in our clinical setting there is a high incidence of penetrating torso trauma the aim of this study is to determine our local accuracy in diagnosing penetrating gastrointestinal injury using CT and to review the local sensitivity and specificity of a select number of CT signs used in making the diagnosis.

As mentioned trajectography has been found to be one of the CT signs with the highest sensitivities for detecting GIT injury and has a noted sensitivity ranging between 77% to 91% depending on the study.[1,2,7] It entails identifying and marking the point of entry on the imaging study and then aligning the reformatted planes so that the tract is visualized in profile.[2,8] The tract is then followed out in order to determine whether it extends up to or through the wall of a segment of the GIT. As GSW have more kinetic energy, which imparts a greater degree of soft tissue injury and surgical emphysema as well as debris along the tract, the tract is more readily apparent when compared to SW tracts.[2] In the majority of SW cases the weapon has also been removed and is not available for evaluation which further impairs estimation of the potential depth of the tract. Additional potential shortfalls that may limit accurate evaluation of the true position, extent and direction of the tract include: migration of soft tissue emphysema, difference in patient position and abdominal tension/distension when being imaged compared to when the injury occurred, patient respiration with changes in thoracic volumes and abdominal volumes, bullet ricochets, slim patients with limited intra-abdominal fat resulting in impaired visualisation and separation of soft tissue, and intraperitoneal free fluid obscuring the tract.[2,7,8]

Enteric contrast opacification, with oral and or rectal contrast, may be performed in order to attempt aiding the diagnosis of retroperitoneal bowel injury. The concern, which initially prompted this additional step to the CT examination of a patient with penetrating torso trauma, is that these retroperitoneal injuries may remain clinically occult for a prolonged period of time resulting in increased morbidity and mortality.[1] Although the administration of enteric contrast is associated with a delay in acquisition of the complete study; increased radiation; and carries a potential aspiration risk, numerous centers felt this to be justifiable as the use of enteric contrast theoretically improved the specificity of the investigation.[1,7] However, enteric contrast leak has been noted to occur in as few as 19% of cases where patients had later confirmed complete disruption of the GIT wall.[2] This may partly be due to the extent of colonic distention and opacification per segment of the GIT that is being opacified. The administration of enteric positive contrast also results in increased radiation to the patient and there is a time penalty, ranging anywhere from 20 – 173 minutes, depending on the desired extent and degree of bowel opacification.[2] In a study performed by Jawad et al that looked at the sensitivity and specificity of single contrast CT (intravenous contrast administration only) for the diagnosis of bowel injuries they found that single contrast CT had a sensitivity and specificity of 88% and 72% respectively.[2] In their article they also mention that previous research based on triple contrast CT (intravenous, oral and rectal contrast) had sensitivities and specificities ranging between 67-100% and 80-97% respectively.[2] Comparing the triple contrast scan sensitivity and specificity to single intravenous contrast scans and taking into consideration the aforementioned radiation and time penalty the routine use of enteric contrast media in these patients is a dilemma worthy of further research.

Another more subjective sign of GIT injury is bowel wall thickening which in one study was reported to occur in only 42% of patients with GIT injury.[1] Bowel wall thickening is furthermore nonspecific and may be secondary to numerous other underlying aetiologies including inflammatory or infective processes. However, the presence of secondary signs such as bowel wall thickening and mesenteric haematoma may aid in a more confident diagnosis of GIT injury when there is an identifiable wound tract extending to the segment of GIT.[2] In contrast to the subjective nature of bowel wall thickening, bowel wall discontinuity is regarded as highly specific for GIT injury but as with enteric contrast leak it has been noted to be a direct sign of GIT injury that is unfortunately infrequently identified.[1,2]

Unlike in blunt abdominal trauma pneumoperitoneum is specific for peritoneal violation but not for GIT injury as air may have tracked into the peritoneal cavity along the wound tract.[1] It has also been noted that pneumoperitoneum may be present in as few as 35% of patients with peritoneal violation.[2] Therefore, the absence of pneumoperitoneum is insufficient to exclude peritoneal violation and the presence of pneumoperitoneum is insufficient to conclude that GIT injury is present. GIT injury may also be missed in the presence of a small amount of pneumoperitoneum if it is incorrectly attributed solely to the presence of a

penetrating tract.[3] In contrast intra-peritoneal free fluid, that is not related to an underlying chronic medical or surgical condition, could result from bleeding along the tract; peritoneal vascular or lymphatic injury; or solid organ injury and has been reported to be present in up to 85% of patients with peritoneal violation. Finding CT features in keeping with peritoneal violation may not be adequate to confirm the presence of GIT injury but being able to exclude peritoneal penetration results in savings related to hospital costs and manpower as these patients may then be safely discharged without the need for a minimum of 24 hour admission, observation with serial clinical examinations, and clinically appropriate biochemical testing.[3,4,6]

Additional CT signs used in the identification of GIT injury, which are mentioned but not extensively elaborated on in a number of studies, include active mesenteric contrast extravasation, intra-luminal bullet fragments, mesenteric haematoma formation, and mesenteric fat stranding adjacent to or in close proximity to the GIT. It is reported that the presence of these additional findings may serve to increase the confidence with which GIT injury is diagnosed in the presence of a clearly definable wound tract that leads up to or through a segment of the GIT.[2]

Considering the value CT imaging adds to patient management with regard to vascular injury identification, grading solid organ injury, identifying peritoneal violation, and that it has been reported that CT results in a N-LAP rate as low as 3,2%, it is clear why associations such as EAST favour the use of CT in conjunction with SCE.[1,3]

However, in patient management (particularly in the state hospital setting and a resource limited setting such as Sub-Saharan Africa) costs and the distributive justice principal must be taken into consideration when deciding on a safe and acceptable management protocol.

To this end a study performed at the Pietermaritzburg Metropolitan Trauma Service (PMTS) by the University of Kwa-Zulu Natal and the University of the Witwatersrand reported that SNOM based on SCE is both safe and cost effective.[9] They found that the potential minimum cost associated with abdominal SW at the PMTS over a period of 5 years would approximate ZAR 20 478 800 and that including mandatory abdominal CT for all patients presenting with abdominal stab wounds would result in an additional cost to management per patient of approximately ZAR 2 120.[9] In support of the argument as to the safety of SCE for the evaluation of patients presenting with penetrating torso trauma two articles were found that assessed SCE for the identification of cases requiring therapeutic surgical intervention which established a sensitivity of 100% and specificity of 98,7% in patients with anterior abdominal SW and a diagnostic accuracy of 95,2% in patients with penetrating posterior abdominal injury, predominantly SW.[5,6] Implying therefore that in regards to the detection of GIT injury requiring therapeutic surgical intervention SCE is at least on par or even superior to CT. Given that CT has been reported to have a prevalence of 8,7% for missing injuries requiring surgical

intervention, patients presenting with penetrating torso trauma would have to undergo a period of SCE prior to safe discharge, except in cases where peritoneal violation has been excluded, in spite of receiving a CT evaluation which was reported as negative for injury requiring surgical intervention.[3]

In respect to this literature review and study the comparative costs of penetrating injury patients management through SCE with and without laparotomy, SCE with and without CT, early CT evaluation with and without laparotomy, a combination of SCE, CT and laparotomy and the influence this has on duration of patient admission, rehabilitation and associated costs all merit further evaluation. The potential cost savings related to the discharge of patients without peritoneal violation diagnosed on CT should also be compared to the costs associated with mandatory admission and SCE for a specified time period if all of these patients were admitted without CT and the subsequent identification of a purely superficial injury.

Research Question

Determine the local sensitivity and specificity for diagnosing GIT injury based on CT examination of patients imaged due to penetrating torso trauma and to review the sensitivity and specificity of some of the CT signs used for making the diagnosis.

Aims

Retrospective analysis of electronic medical records and CT imaging findings in patients presenting to the Pelonomi Academic Hospital trauma unit with penetrating torso trauma in order to assess which select imaging factors have the highest sensitivity and specificity for accurately diagnosing GIT injury as well as a review of the local overall sensitivity and specificity with which GIT injury was diagnosed.

Objectives

1. Review the CT reports for the patients that presented with penetrating trauma and received CT imaging prior to surgery or discharge (after a minimum of 24 hours of SCE) in order to determine the local sensitivity and specificity for diagnosing GIT injury on CT imaging.

2. Determine the sensitivity and specificity of the following CT signs for detecting GIT injury:
   - GIT wall disruption
   - GIT wall thickening
   - Superficially visible tract in the direction of the GIT

- Trajectography: clear tract up to the GIT
- Mesenteric IVI contrast extravasation
- Mesenteric haematoma
- Mesenteric fat stranding adjacent to stomach or bowel loops
- Soiling adjacent to the colon
- Abnormal small bowel enhancement
- Intraperitoneal free air distant to the wound tract
- Interloop fluid between small bowel loops
- Intra-abdominal free fluid distant to the tract in the presence of solid organ injury
- Intra-abdominal free fluid distant to the tract in the absence of solid organ injury
- Bullet fragments within the GIT lumen

3. Determine the sensitivity and specificity of colorectal contrast extravasation in detecting colorectal injury in patients who received colorectal contrast opacification as well as review the percentage of patients that had optimal colorectal contrast opacification per segment of the colon.

Sensitivities and specificities for the different criteria evaluated will be obtained if the numbers permit

In order to obtain sensitivities and specificities each of the factors assessed will be compared to the patient's intra-operative findings or if the patient did not receive surgical intervention and was discharged after a minimum of 24 hours serial clinical examinations then it will be presumed that there was no significant gastrointestinal injury

Hypothesis

Due to our high burden of trauma resulting in a high turnover of trauma based scans our local sensitivity and specificity for diagnosing GIT in patients presenting with penetrating trauma should at least be on par with that of international centres. The sensitivity and specificity of certain CT signs that are used to assist in diagnosing penetrating GIT trauma may show some variation when compared to international studies as the majority of local penetrating trauma occurs due to low velocity stab wounds inflicted with a range of weapons, from knifes to machetes and broken bottles, instead of gunshot wounds and the fact that the majority of weapons have been removed from the patient's body prior to presentation thereby impairing the estimation of the possible extent of the wound tract.

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Chapter 2: Manuscript as intended for publication

Title

The value of CT evaluation for possible GIT injury in penetrating torso trauma: a local study

Abstract

Background

In evaluating penetrating torso trauma patients suitable for conservative management CT and/or serial clinical examinations may be used. However, a recent review found that CT had 8,7% false negatives for identifying gastrointestinal injury. Given our hospital's trauma prevalence the review of our CT accuracy in diagnosing gastrointestinal injury is of merit.

Objectives

Determine local accuracy for identifying gastrointestinal injury on CT and review the sensitivity and specificity of certain signs in the detection thereof locally.

Method

Clinical records and CT scans for a total of 114 patients with penetrating torso trauma were reviewed. CT's sensitivity and specificity for detecting GIT injury and of certain CT findings related to GIT injury was calculated.

Results

Of the 114 cases reviewed 44 (38,6%) had GIT injury. Eighty-one (71,1%) had stab wounds. A superficially visible tract in the direction of the GIT had the highest sensitivity (93,2%; 95% CI: 81,8-97,7) but lacked specificity (64,3%; 95% CI: 52,6-74,5). GIT wall thickening and remote intraperitoneal free fluid without solid organ injury both had high sensitivity (77,3% and 73,5% respectively) and specificity (82,9% and 89,7%).

The identification of GIT injury with CT had a sensitivity of 93,2% (95% CI: 81,8% - 97,7%) and specificity of 84,3% (95% CI: 74.0% - 91.0%).

Conclusion

Despite some CT signs having good local sensitivity and specificity for detecting GIT injury with penetrating torso trauma, CT in isolation is inadequate to exclude GIT injury and should be used in conjunction with clinical examination.

Article

Introduction

In patients with penetrating torso trauma with generalized peritonitis, or who are haemodynamically unstable, expert opinion is that they should progress to explorative laparotomy (LAP) without delay. [1,2] Both the Eastern Association for the Surgery of Trauma (EAST) and the Western Trauma Association (WTA) advocate selective non operative management (SNOM) for the remainder of patients.[2] The two associations differ in their work up of those patients - EAST recommends serial clinical examinations (SCE) and computed tomography (CT) of the abdomen and pelvis whereas WTA guidelines advocate the use of, or a combination of, SCE, local wound exploration, or CT based on available resources and provider preference.[2]

CT's ability to detect vascular injury amenable to angioembolisation, or which requires LAP, is invaluable in the setting of penetrating torso trauma.[3] Additionally, CT can evaluate intra-abdominal solid organ injury according to the American Association for the Surgery of Trauma (AAST) injury graduations. These grades, in conjunction with clinical evaluation, determine which patients are likely to be managed successfully with SNOM and which require LAP.[3-6] Patients without peritoneal violation on CT may be discharged without further work up, decreasing hospital admissions and resource utilisation in patients who would otherwise have had to receive 12-24 hours of SCE and blood tests prior to discharge.[2,7,8] However, where CT falls short is in the evaluation and exclusion of possible gastrointestinal (GIT) injuries. There are a myriad of direct and indirect CT signs which are considered to be indicative of hollow viscus injury – including bowel wall discontinuity (highly specific but rarely seen)[3], wound tract extending up to or through bowel (seen in up to 77% of patients with GIT injury)[1,3], leakage of oral or rectal contrast (highly specific but in some studies only seen in 15-29% of cases of full thickness injuries)[1,9], mesenteric fat stranding in region of bowel loops, active mesenteric vascular contrast extravasation, mesenteric haematoma, interloop fluid, and bowel wall thickening (seen in approximately 42 % of bowel injury patients).[1,3] A 2018 systematic review demonstrated a prevalence of 8,7% false negative CT scans in patients who required LAP and that approximately 40% of these patients had hollow viscus injury.[2]

Given our clinical setting in which there is a high incidence of penetrating torso trauma, and that numerous patients receive CT whilst awaiting theatre for a clinically warranted LAP, it is of value to review our local accuracy in diagnosing penetrating GIT injury using CT and to determine which CT signs most aid the process.

Research methods and design

Setting

Pelonomi Academic Hospital of Bloemfontein has a level one trauma centre which is the referral centre for the Free State and additionally assesses and manages local trauma patients. In just a 6-month period (January to June 2019) the department managed 598 patients with penetrating trauma. Certain patients, at clinician's discretion, receive CT imaging for work up and to assist with management.

Patients and Materials

The Pelonomi Academic Hospital trauma registry was used to identify all adult patients, 18 years or older, who presented between 18 December 2017 and 18 June 2019 with penetrating torso trauma and subsequently received a CT that included the torso, extending from above the diaphragmatic domes to below the pubic symphysis, prior to surgery or discharge after a minimum of 24 hours serial clinical examination with no clinical suspicion of GIT injury. Penetrating torso trauma was defined as an externally penetrating skin injury, due to a foreign object, that was anywhere from the nipples to the perineum. Patients were excluded if they had their first CT after a laparotomy was performed, CT study was unavailable, the injury was entirely thoracic, the injury was superficial to the peritoneum, no clinical records were found, or patients who were discharged prior to a minimum of 24 hours of SCE. The total number of patients who satisfied these criteria amounted to 114.

All patients were scanned from above the diaphragm to below the symphysis pubis on a GE Discovery HD 750 64 slice multidetector computed tomography (MDCT) machine with a slice thickness of 5mm and at least two intravenous contrast phases (arterial and portovenous). Delayed phase and administration of colorectal contrast was based on the referring physician's request or the radiology registrar's discretion. For colorectal contrast the departmental protocol is to add 20ml of Omnipaque 300 or 350 (depending on availability) to 1L Saline or Ringer's lactate and this is then passively run in per rectum. Depending on intravenous access, contrast is injected at a rate of 3ml- 5ml/s and a region of interest is placed on the abdominal aorta in order to commence scanning once an adequate level of contrast opacification of the aorta has occurred. Fifty-four of the study's patients received colorectal contrast opacification. Colorectal contrast opacification was graded per colonic segment as optimal if the colon was well distended and opacified with contrast and suboptimal if there was suboptimal distension and/or suboptimal contrast opacification.[13]

Images were reviewed on the AGFA PACS (version 6.4) for patients imaged between 18 December 2017 and mid-January 2019 and on FUJIFILM Synapse 5.5.000 PACS for those imaged from mid-January 2019 until 18 June 2019 (Transition between PACS systems occurred in January 2019).

Design and procedure

A retrospective, cohort analytical study was performed. The initial imaging analysis was conducted by the radiology registrar on duty and later reviewed with one of the department's radiologists, all of whom have more than 10 years of experience in evaluating cross sectional imaging. The first author, a registrar with approximately 3 years of experience in body CT interpretation, subsequently reviewed all of the studies to document CT signs which were not specifically commented on initially.

Clinician notes were reviewed, and a data sheet was used to record demographics as well as relevant clinical examination findings (single injury or multiple injuries and whether these were gunshot or stab wounds). A select number of CT findings and whether imaging features were suggestive of GIT injury and reported as such were recorded. Additionally, whether GIT injury was found during LAP, or whether the patients were discharged after a minimum of 24 hours SCE without developing clinical features suggestive of underlying GIT injury, were also recorded.

Included CT findings were whether the patient received rectal contrast (and adequacy of opacification per colonic segment); presence of contrast leak; GIT wall disruption; presence of a penetrating wound trajectory in the direction of the GIT; clearly identifiable wound tract extending up to the wall of a segment of the GIT (trajectography); soiling adjacent to the colon; abnormal small or large bowel mural enhancement; GIT mural thickening; mesenteric fat stranding, haematoma formation, or contrast extravasation; interloop fluid; subdiaphragmatic free air noted on radiographs; intraperitoneal free air or fluid remote from the tract; and presence of solid organ injury.

Data analysis

Statistical analysis of the data obtained and recorded on the data sheet was performed by the Department of Biostatistics at the University of the Free State, in order to obtain the relevant sensitivities and specificities of the variables. Results were summarized by frequencies and percentages (categorical variables) and medians and interquartile range (IQR: 25 to 37). Sensitivity and specificity of various CT signs to detect GIT injury were calculated with 95% confidence intervals. Patients were regarded as positive for having GIT injury if, according to the notes, injury was noted during LAP and negative if no injury was found during LAP or if the patient was discharged without developing clinical features suggestive of GIT injury during a minimum of 24 hours of SCE.

Ethical considerations

Ethical approval for this study was obtained from the University of the Free State Health Sciences Research Ethics Committee (UFS-HSD2019/2192/2605) and Free State Department

of Health (FS_202002_004). Patient data was anonymized after interpretation by the primary researcher.

Results

CT imaging and clinical notes were reviewed for 114 patients ranging between 18 and 68 years (median 30, IQR 25 to 37) of which 99 (86,8%) were male and 15 (13,2%) female. There were 81 (71,1%) cases of stab wounds and 33 (28,9%) gunshot cases. The majority of cases, 91 (79,8%) had a single penetrating injury. Forty-four (38,6%) patients included in the study had GIT injury and 54 (47,4%) of the 114 patients received colorectal contrast. Of the 54 patients who received colorectal contrast 15 (27,8%) had colonic injury and 9 (60%) of these had colorectal contrast leak. The percentage of patients with optimal colorectal contrast opacification per segment of the colon is set out in table 1 with decreasing opacification distally - in more than 75% of patients there was suboptimal opacification past the hepatic flexure.

Table 2 Percentage of optimal colorectal contrast opacification, per segment of the colorectum, in the 54 patients who received colorectal contrast

Segment opacified	Percentage of cases with optimal opacification
Rectum	96,3%
Sigmoid colon	90,7%
Descending colon	83,3%
Splenic flexure	68,5%
Transverse colon	25,9%
Hepatic flexure	22,2%
Ascending colon	16,7%
Caecum	14,8%

Table 2 provides a representation of the frequency with which a sign was observed and table 3 provides an overview of the sensitivity and specificity, with associated confidence intervals, for those CT signs. The signs with the highest sensitivity for identifying GIT injury were a superficially visible tract in the direction of the GIT, GIT wall thickening and intra-abdominal free fluid remote from the tract without solid organ injury.

Table 2: Frequency with which the CT signs occurred

Signs	Number of cases in which the sign was present	Percentage of cases in which the sign occurred
GIT Wall disruption	15/114	13,2%
Superficially visible tract in the direction of the GIT	66/114	57,9%
Trajectography: clear tract up to the GIT	23/114	20,2%
Active mesenteric IVI contrast extravasation	3/114	2,6%
Mesenteric haematoma	22/114	19,3%
Mesenteric fat stranding adjacent to stomach or bowel loops	38/114	33,3%
Colorectal contrast leak *	9/54	16,7%
Soiling adjacent to the colon	4/114	3,5%
Abnormal small bowel enhancement	17/114	14,9%
Intraperitoneal free air distant to the wound tract	34/114	29,8%
GIT wall thickening	46/114	40,4%
Interloop fluid between small bowel loops	39/114	34,2%
Intra-abdominal free fluid distant to the tract in the presence of solid organ injury	27/114	23,7%
Intra-abdominal free fluid distant to the tract in the absence of solid organ injury	28/114	24,6%
Bullet fragments within the GIT lumen**	1/33	3,0%

* Calculated for the 54 patients who received colorectal contrast

** Calculated for the 33 patients who sustained gunshot wounds

Table 3: Sensitivity and specificity of evaluated CT signs for GIT injury

Signs	Sensitivity (95% CI)	Specificity (95% CI)
GIT Wall disruption	34,1% (21,9; 48,9)	100% (94,8; 100,0)
Superficially visible tract in the direction of the GIT	93,2% (81,8; 97,7)	64,3% (52,6; 74,5)
Trajectography: clear tract up to the GIT	43,2% (29,7; 57,8)	94,3% (86,2; 97,8)
Active mesenteric IVI contrast extravasation	2,3% (0,4; 11,8)	97,1% (90,2; 99,2)
Mesenteric haematoma	43,2% (29,7; 57,8)	95,7% (88,1; 98,5)
Mesenteric fat stranding adjacent to stomach or bowel loops	56,8% (42,2; 70,3)	81,4% (70,8; 88,8)
Colorectal contrast leak *	36,0% (20,2; 55,5)	100% (88,3; 100,0)
Soiling adjacent to the colon	9,1% (3,6; 21,2)	100% (94,8; 100,0)
Abnormal small bowel enhancement	34,1% (21,9; 48,9)	97,1% (90,2; 99,2)
Intraperitoneal free air distant to the wound tract	61,4% (46,6; 74,3)	90% (80,8; 95,1)
GIT wall thickening	77,3% (63,0; 87,2)	82,9% (72,4; 89,9)
Interloop fluid between small bowel loops	61,4% (46,6; 74,3)	82,9% (72,4; 89,9)
Intra-abdominal free fluid distant to the tract in the presence of solid organ injury	60% (31,3; 83,2)	48,8% (34,3; 63,5)
Intra-abdominal free fluid distant to the tract in the absence of solid organ injury	73,5 % (56,9; 85,4)	89,7% (73,6; 96,4)
Bullet fragments within the GIT lumen**	4,8% (0,8; 22,7)	100% (75,7; 100,0)

* Calculated for the 54 patients who received colorectal contrast

** Calculated for the 33 patients who sustained gunshot wounds

The conclusions in the reports of the CT studies were 93,2% specific (95% confidence interval: 81,8% - 97,7%) for identifying GIT injury with a specificity of 84,3% (95% confidence interval: 74.0%; 91.0%).

Discussion

SNOM has become the standard for patients with penetrating torso trauma, without generalized peritonitis and who are haemodynamically stable.[2] There is however no universal guideline of what SNOM entails nor regarding the duration of SNOM prior to safe patient discharge.[2] In the literature the majority of penetrating GIT injury cases requiring surgical repair become clinically apparent within 12-24 hours and hence a minimum of 24 hours of SCE, prior to discharge, was used in this study to classify patients who did not receive a LAP as not having GIT injury.[2,7,8] With regard to what SNOM entails, EAST advocates a combination of SCE and CT, whilst the WTA makes allowances for available resources and provider preference adding the option of local wound exploration.[2] A South African study found SNOM based primarily on clinical grounds to be safe and cost effective and advocated this approach in resource constrained environments.[10] Locally CT and SCE are used in conjunction for patients with penetrating torso trauma based on clinical suspicion of intra-abdominal injury and the managing clinicians preference. Due to finite resources not all patients who clinically merit explorative laparotomy have prompt theatre access and might therefore receive CT evaluation prior to surgery.

CT's sensitivity and specificity for identifying peritoneal violation has been reported as up to 97% and 98% respectively whilst for identifying traumatic GIT injury sensitivity between 67-100% and specificity of between 80-97% were reported. [1,9] Direct CT signs used for evaluation of GIT include GIT wall disruption, colorectal contrast leak, and intraluminal bullet fragments, whereas indirect signs include wound tract extending to/penetrating bowel wall, mesenteric vascular contrast extravasation, fat stranding adjacent to loops, mesenteric haematoma and interloop fluid. [1,3,11]

Wall discontinuity and contrast leak are highly specific for GIT injury but it has been reported that wall discontinuity is rarely seen and enteric contrast leak may occur in as few as 19% of cases with transmural defects.[1,3] In this study 40% of the patients who had received colorectal contrast and had a colorectal injury did not have colorectal contrast extravasation. Therefore the absence of contrast extravasation is inadequate to exclude colorectal injury. Assessment of adequacy of colorectal contrast opacification, per colonic segment, was modeled on a study by Dreizin et al.[12] Optimal opacification was considered as the sum of a well distended colon that was optimally opacified with contrast.[12] In this study colorectal contrast opacification progressively decreased from the rectum to the caecum and ranged from 96,3% in the rectum to 14,8% in the caecum. This likely impacts on contrast leak in patients with colorectal injury.

As enteric opacification is inadequate to exclude GIT injury and a 2018 study found that intravenous only contrasted CT had a comparable accuracy to triple-contrast CT (intravenous, rectal, and oral) for identifying bowel injuries it is debatable whether rectal contrast should be included in the initial CT, also considering increased radiation and time taken to administer the contrast. [3,9]

Intraperitoneal free air and fluid are nonspecific for GIT injury as they may be introduced during peritoneal violation and free fluid may arise from concomitant solid organ injury.[1-3] One study reported pneumoperitoneum to be an infrequent finding visible in 35% of patients with peritoneal violation.[3] In this study 61,4% had pneumoperitoneum remote from the tract. Intraperitoneal free fluid had a sensitivity and specificity of 60% and 48,8% respectively, in this study, in patients with concomitant solid organ injury. This improved significantly in the absence of a solid organ injury to 73,5% and 89,7% respectively, supporting that intraperitoneal free fluid is nonspecific for GIT injury and highlighting that with concomitant solid organ injury there is a greater chance of GIT injuries being missed.

Bowel wall thickening is a subjective sign and in one study was reported in only 42% of patients with GIT injury.[1] In this study bowel wall thickening occurred in 77,3% but as segmental bowel wall thickening has a broad differential if taken in isolation, it is of questionable value.

Trajectography entails identifying the point of entry and then aligning reformatted planes to visualise the tract in profile to determine whether there is GIT involvement.[3,12] Trajectogrsaphy's reported sensitivity ranges from 77%- 91% and specificity between 50-78% depending on the proportion of GSW to SW and single to multiple penetrating wounds that were present in each study.[1,3,12] Identification of the penetrating tract may be impaired in SW when compared to GSW due to the lower kinetic energy of SW and thus diminished soft tissue injury, surgical emphysema and debris along the tract.[3] In the majority of SW cases the weapon has been removed and is unavailable impairing estimation of potential tract depth. Penetrating tracts may also be misjudged due to patient respiration and due to altered patient position and posture from time of injury to CT scan.[3] In this study population 71,1% of patients had SW and in 79,8% of the 114 cases there was a single penetrating injury present. It was recorded whether the superficial penetrating tract was in the direction of the GIT, and in those cases trajectography was performed. A superficial tract towards the GIT was highly sensitive (93,2%) but less specific (64,3%). When trajectography was performed in these cases the sensitivity decreased to 46,3% however the specificity increased to 84%. The diminished local accuracy of trajectography could be related to the number of SW, reduced kinetic energy with a less prominent tract compared to GSW and a myriad of additional factors including body habitus, type of weapon, intra-abdominal free fluid, and lack of clear demarcation of the sites of penetration prior to imaging.

Additional CT signs, which are briefly mentioned in a number of studies, include active mesenteric contrast extravasation, intra-luminal bullet fragments, mesenteric haematoma formation, and mesenteric fat stranding in region of the GIT. In this study each of these signs was noted to have a sensitivity of 2,3%, 4,8%, 43,2%, and 56,8% respectively. The very low sensitivity of active mesenteric contrast extravasation and intra-luminal bullet fragments may be due to an undetectable bleeding rate, the number and varying ballistics of GSW. [3]

Our local sensitivity for detecting GIT injury was 93,2% (CI: 81,8% - 97,7%), which is comparable to other studies where the sensitivity ranged between 67%-100%.[1,9] The 6,8% false negative cases is in concordance with a systematic review and meta-analysis which found a 8,7% prevalence of false negative cases requiring surgical intervention.[2] Two articles that assessed SCE for identification of cases requiring therapeutic surgical intervention established a sensitivity of 100% and specificity of 98,7% in patients with anterior abdominal SW and a diagnostic accuracy of 95,2% in patients with penetrating posterior abdominal injury, predominantly SW.[7,8] Implying therefore that in regards to detection of GIT injury requiring therapeutic surgical intervention SCE is on par or superior to CT and should form the foundation of the management of patients presenting with penetrating torso trauma.

Limitations

In the course of this study various limitations and potential sources of bias were identified.

Two patients were discharged after CT and a minimum of 24 hours SCE who should have received LAP based on clinical and/or CT findings and for whom there was no surgical confirmation of GIT injury. One patient refused surgery and the other was clinically stable after 3 days awaiting a theatre slot.

Based on the Pelonomi Academic Hospital trauma department statistics, there were initially 208 cases with penetrating torso trauma that occurred within the specified time frame. Of these 30 had no peritoneal violation, 42 had no images available on the PACS (intermittent server technical difficulties resulting in loss of images) and in 14 cases no medical records, other than the original trauma assessment, could be traced. Thus 56 cases were excluded which may have influenced the results.

Conclusion

In this study the CT signs with the highest sensitivity, and least disparity between sensitivity and specificity, were GIT wall thickening and intra-abdominal free fluid in the absence of solid organ injury. A superficially visible tract in the direction of the GIT had the highest sensitivity of the signs evaluated but a much lower specificity. Use of trajectography increased the specificity but reduced the sensitivity, contrary to international studies.

Overall our local sensitivity for detecting GIT injury was 93,2 % which is on par with international studies. Of concern is the local and international high false negative rate of cases requiring surgical repair.[2]

When contrasted with research evaluating SCE for detection of GIT injury CT appears to fall short as SCE was noted to have a sensitivity and specificity of up to 100% and up to 98,7% respectively.[7,8] Hence SCE's importance in the assessment and management of penetrating torso trauma should be emphasized in protocols.

Acknowledgement and Ethical consideration statements

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The authors wish to thank Dr JE Fox (Registrar in Diagnostic radiology, Universitas hospital) with assisting with proof reading of the article.

Competing interests
The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

The views within this article are solely those of the researchers and not an official position of the institution

Authors contributions:

- L.B. was the principal investigator who planned and executed the study, after obtaining ethical approval, and subsequently wrote the manuscript
- G.J. provided input on the protocol and data sheet, did statistical analysis of the data obtained, and critically evaluated the manuscript and approved the final version.
- J.J.v.R. was the study leader and critically evaluated the manuscript and approved the final version.

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Data availability statement:
Data sharing is not applicable in this article as no new data were created or analysed in this study.

Disclaimer:

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors

Ethical considerations

Ethical approval for this study was obtained from the University of the Free State Health Sciences Research Ethics Committee (UFS-HSD2019/2192/2605) and Free State Department of Health (FS_202002_004). Patient data was anonymized after interpretation by the primary researcher.

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List of Appendices:

UFS Health Sciences Research Ethics Committee Approval

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

UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

Health Sciences Research Ethics Committee

23-Apr-2020

Dear **Dr Lilanie Biddulph**

Ethics Clearance: **The use of computed tomography for the detection of gastrointestinal injury in patients with penetrating torso trauma: a central South African experience.**

Principal Investigator: **Dr Lilanie Biddulph**

Department: **Clinical Imaging Sciences Department (Bloemfontein Campus)**

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-HSD2019/2192/2605**

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.

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(2006); 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; The International Conference on Harmonization and Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH Tripartite), Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the HSREC of the Faculty of Health Sciences.

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

Dr. SM Le Grange
Chair : 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
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Free State Department of Health Ethics Approval

health
Department of Health
FREE STATE PROVINCE

02 March 2020

Dr L Biddulph
Dept. of Clinical Imaging Science
UFS

Dear Dr L Biddulph

Subject: The use of computed tomography (CT) for the detection of gastrointestinal injury in patients with penetrating torso trauma: a central South African experience.

- Please ensure that you read the whole document. Permission is hereby granted for the above – mentioned research on the following conditions:
- Serious Adverse events to be reported to the Free State department of health and/ or termination of the study via the serious adverse events reporting system of the Free State Department of Health.
- Ensure that your data collection exercise neither interferes with the day to day running of **Pelonomi Hospital** nor the performance of duties by the respondents or health care workers.
- Confidentiality of information will be ensured and please do not obtain information regarding the identity of the participants without the consent from the potential participants.
- **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 the Free State and to Free State Department of Health.
- Any amendments, extension or other modifications to the protocol or investigators must be submitted to the Ethics Committee of the University of the Free State and to 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** sebeelats@fshealth.gov.za / makenamr@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 Institution Manager on commencement for logistical arrangements see 2nd page for contact details.**
- Department of Health to be fully indemnified from any harm that participants and staff experiences in the study to mitigate against any possibility of litigation emanating from the study.
- Researchers will be required to enter in to a formal agreement with the Free State department of health regulating and formalizing the research relationship (document will follow)
- **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

Dr D Motau
HEAD: HEALTH
Date: 5/03/2020

Head : Health
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www.fs.gov.za

Approval to do the research project from the head of department

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MASTER OF MEDICINE

This is to certify that the Departmental Research Meeting approved of the following MMed research protocol:

DATE OF MEETING	18 October 2019
DEPARTMENT	Clinical imaging Sciences | Radiology
STUDENT NUMBER	
INITIALS AND SURNAME OF CANDIDATE	L Biddulph
NAME OF DEGREE	
SUPERVISOR	Dr S Janse van Rensburg
CO-SUPERVISOR	

TITLE OF THE RESEARCH PROJECT
The use of computed tomography for the detection of gastrointestinal injury in patients with penetrating torso trauma: a central South African experience.

RESEARCH CHAMPION **DATE** 18 OCT 2019 / 7 JAN 2020

SUPERVISOR(S) **DATE** 7 JAN 2020

HEAD OF THE DEPARTMENT **DATE** 7 JAN 2020

Research protocol

Background to this study:

My original study protocol with the title "Does colorectal positive contrast administration per rectum contribute to the emergent diagnostic accuracy of computed tomography (CT) for identifying colorectal injury in patients with penetrating torso trauma?" was approved by the Health Science Research Ethics Committee (UFS-HSD2018/1592) as well as by the Free State department of Health (FS 201903_006) by April 2019. Post my intermediaries I started collecting data and realised that due to technical factors I would no longer be able to access any patient imaging records prior to 17 December 2017 (original proposed timeline of 1 October 2016 – 30 September 2018). I subsequently made an amendment to my study so that the timeline would extend from 18 December 2017 to 18 June 2019. Unfortunately, after gathering the data, when I reviewed it with Professor Joubert I came to the realisation that I had insufficient patient numbers to answer my original research question. I am still unable to access the electronic imaging records for any patients prior to 17 December 2017 and can therefore not request another amendment to the timeline. This has prompted me to perform another literature review with a new protocol that will be using the same group of patients but requiring that I gather additional retrospective data for each patient in order to answer a new set of aims and objectives. My intention was to submit this new protocol before the submission date for November 2019 but as it then became apparent that my original study leader would be leaving the department I was advised to rather get a new study leader and therefore there was a delay in the planned submission date of my new protocol.

Title:

The use of computed tomography for the detection of gastrointestinal injury in patients with penetrating torso trauma: a central South African experience

Researcher:

Dr L Biddulph

Supervisor:

Dr J Janse vanRensburg

Introduction

Mandatory explorative laparotomy (LAP) for penetrating torso trauma was born in the era of the world wars where it was assumed that penetrating wounds were strongly associated with underlying visceral injuries and that a delay in surgical management would be associated with a higher rate of morbidity and mortality (1). By the 1960's the trend of mandatory LAP for all penetrating torso trauma was shifting to an entity known as selective nonoperative management (SNOM) in haemodynamically stable patients with anterior abdominal stab

wounds (2). This approach followed the realisation that routine LAP for all patients with penetrating torso trauma led to nontherapeutic laparotomy (NtherLAP) rates as high as 35-53% (3). In the subsequent years SNOM has branched out and is being applied to stab wounds in different regions of the torso and even to penetrating injuries secondary to gunshot wounds (GSW). This is due to the success of well applied SNOM in reducing patient hospital stay, especially of those patients who would have had NtherLAP with its associated possible complications and increased costs.

Currently there is a consensus amongst experts that patients with penetrating torso trauma that are haemodynamically unstable and/or have generalised peritonitis should progress to LAP without delay. For the rest of the patients both the Eastern Association for the Surgery of Trauma (EAST) and the Western Trauma Association (WTA) advocate SNOM. Where these two associations differ is in their work up approach for patients who qualify for SNOM. EAST recommends serial clinical examinations (SCE) and computed tomography (CT) of the abdomen and pelvis whereas the WEST guidelines advocate the use of one or a combination of SCE, local wound exploration (LWE), or CT based on available resources and provider preference. (3)

LWE:
LWE is a sterile surgical technique for exploring the wound and is deemed positive if the wound extends through the facia. If all patients with positive LWE were taken for LAP it would result in an estimated 50% NtherLAPs (4). It is also of limited value in obese patients or patients with penetrating trauma to the back or flanks. (5)

CT:
Patients who are shown to not have peritoneal violation on CT may be safely discharged without further work up thereby decreasing the amount of unnecessary hospital admissions and use of resources in patients who might have been kept for 24-48 hours of serial clinical examinations and blood tests prior to discharge (6). CT is also of great value in the evaluation of the intra-abdominal solid organs in cases of penetrating injury as it can be used to grade the severity of the injury based on the AAST criteria which in turn, with the patient's clinical picture, is used to determine whether the patient can potentially be managed nonoperatively, with angioembolisation, or requires LAP. (7-9). Patients with higher grades of injury to the liver are less likely to have successful nonoperative management and are more likely to benefit from LAP. (8). However, where CT falls short is in the evaluation and exclusion of possible gastrointestinal injuries. There is a myriad of direct and indirect CT signs which if found are considered to be indicative of hollow viscus injury and some of these signs include bowel wall discontinuity (highly specific but rarely seen), wound tract extending up to or through bowel (seen in up to 77% of patients with GIT injury), leakage of oral or rectal contrast (highly specific but noted in some studies to only be seen in 15-29% of cases of full thickness injuries), mesenteric fat stranding adjacent to or close to bowel loops, active mesenteric

contrast extravasation; mesenteric haematoma, interloop fluid, and bowel wall thickening (subjective and seen only in approximately 42 % of patients with bowel injury). *(2,9-10)*. In their systematic review published in 2018 Baron and colleagues found that across various studies there was a prevalence of 8,7% of false negative CT scans in patients who actually required LAP and that approximately 47% of these patients had hollow viscus injury. (3) They therefore concluded that CT cannot be the sole determinant of patient management.

SCE:

Diagnostic accuracy of the initial abdominal examination for determining which patients required LAP was shown to be 95,2% in a study done by Demeteriades et al (5). At the Pietermaritzburg Metropolitan Trauma Service (PMTS) in South Africa patients who qualify to be managed nonoperatively are managed with SCE which consists of 2 hourly monitoring of vital signs, regular examination by the same trauma surgeon, and monitoring of the leucocyte trend. If these patients develop features suggestive of sepsis then they are taken for emergency LAP. The PMTS patients with penetrating trauma, who qualify for SNOM, are not routinely taken for CT examination. In one study performed at this hospital they found that physical examination had an accuracy of 90% for identifying patients with organ injury and in another study at this same hospital they showed SCE to be a safe and a cost effective way of managing patients with abdominal stab wounds and that if all of their patients who were successfully managed with SNOM had additional mandatory CT or mandatory diagnostic LAP or laparoscopy then the associated additional costs for these patients would have added an estimated R440 680, R530 730 or R2 695 140 respectively per year. (11,12) There is also a potential morbidity of approximately 20% in patients who undergo NtherLAP with associated prolonged hospital stay and additional costs. (12,13).

At present SCE is clearly the safest and most cost effective way of managing patients who initially qualify for SNOM. CT is a beneficial adjunct as it can identify the patients without peritoneal violation who may be safely discharged without further evaluations or a longer hospital stay and it is used to grade the severity of solid organ injury according to the AAST criteria which then gives the attending clinician an indication as to the likelihood of the possible success of SNOM in that specific patient and whether or not the patient should receive additional intervention such as angioemobolisation or LAP. As it has been noted in international studies (where CTs are reported by qualified, experienced radiologists) that CT falls short in the diagnosis of gastrointestinal injuries this article aimed to look at the local experience (where CTs are initially reported by radiology registrars with varying degrees of experience) with regards to diagnosing GIT injury during CT evaluation and which factors, or combination of factors, had the highest sensitivity and specificity for accurately diagnosing GIT injury. A statistical evaluation with determination of sensitivity, specificity and a likelihood ratio of certain factors, or combination of factors, for indicating the presence of GIT injury and the subsequent need for LAP can then be made with the aim of assisting in limiting the number of possible negative laparotomies in patients with penetrating torso trauma.

Aims and objectives:

Aim:

Retrospective analysis of electronic medical records and CT imaging findings in patients presenting to the Pelonomi Academic Hospital trauma unit with penetrating torso trauma in order to assess which imaging factors, or combination of imaging factors, have the highest sensitivity and specificity for accurately diagnosing GIT injury.

Objectives:

- Sensitivities and specificities for the different criteria evaluated will be obtained if the numbers permit
- In order to obtain sensitivities and specificities each of the factors assessed will be compared to the patient's intra-operative findings or if the patient did not receive surgical intervention and was discharged after a minimum of 24 hours serial clinical examinations then it will be presumed that there was no significant gastrointestinal injury

1. Determine the sensitivity and specificity of penetrating trajectory towards the hollow viscus for identifying gastric, small bowel, or large bowel injuries respectively.
2. Determine the sensitivity and specificity of gastrointestinal wall thickening for identifying gastric, small bowel, or large bowel injuries
3. Determine the sensitivity and specificity of gastrointestinal wall disruption for identifying gastric, small bowel, or large bowel injuries
4. Note the extent and adequacy of colorectal contrast opacification and whether there was a contrast leak in patients who received rectal contrast and had documented colorectal injury during surgical exploration.
5. Determine the sensitivity and specificity of colorectal contrast leak large bowel injuries
6. Determine the sensitivity and specificity of soiling adjacent to the colon for identifying large bowel injuries
7. Determine the sensitivity and specificity of intraperitoneal free air at a site distant to the tract for identifying gastrointestinal bowel injuries
8. Determine the sensitivity and specificity of abnormal small bowel enhancement, mesenteric fat stranding close to small bowel loops, mesenteric haematoma, mesenteric contrast extravasation, and interloop fluid for identifying small bowel injuries
9. Determine which combination of factors have the highest sensitivity and specificity for accurately diagnosing GIT injury.

Research methods and design

Study design:

Retrospective analytical cross sectional study

Setting:

Study undertaken at a central South African level 1 government trauma centre (Pelonomi Academic Hospital).

Study population and sampling:

Retrospective sequential sampling, starting from 18 December 2017 until 18 June 2019, of all patients who are 18 years or older and presented to the trauma department at Pelonomi Academic hospital with penetrating torso injury and subsequently received evaluation with CT scan prior to explorative laparotomy or discharge from the department after CT and serial clinical examinations for a minimum of 24 hours.

During data collection for the initially approved study it was noted that 114 patients qualify to form part of this study based on the original inclusion and exclusion criteria. Compared to some of the previous topic related studies done this is a justifiable sample size for the time period as those studies had between 3-7 patients per month duration of those studies. (1,9,14)

Inclusion criteria:

1.Patients with penetrating torso trauma who presented to the trauma department at Pelonomi Academic Hospital between 18 December 2017 until 18 June 2019 and who received CT evaluation which included the torso prior to LAP or discharge after a minimum of 24 hours SCE

2. Patients 18 years and older

Exclusion criteria:

1. Patients younger than 18 years
2. First CT evaluation only after LAP
3. Patients discharged prior to a minimum of 24 hours SCE
4. Injury entirely above the diaphragm
5. Superficial injury that clearly does not violate the peritoneum
6. Patients for whom no records can be found

Measurements:

1. Evaluation:
    - Retrospective review of patient's CT imaging for direct and indirect signs of gastrointestinal injury compared with the patient's electronic data in order to correlate the CT findings with the patient's surgical findings or the presumption

that there was no gastrointestinal injury if the patient did not receive surgery and was discharged after a minimum of 24 hours of serial clinical examinations without.

- CT imaging for patients with surgically documented bowel injury and who received colorectal contrast during the CT examination will also be reviewed to determine the extent and adequacy of colorectal contrast opacification and the presence of contrast leak.
- The findings will be documented on a datasheet. The patient file numbers will be removed prior to submission for statistical evaluation to further ensure patient confidentiality

Methodology and measurement errors:

Limitations

1. Incomplete patient record keeping
2. Patients discharged without at least receiving serial examinations for a minimum of 24 hours
3. Inability to access patient record or imaging based on technological factors

Discrepancies with noting patient information will be limited by revising data captured for every 5th patient after every 20 patients that have been done.

Pilot study:

A pilot study based on the original approved protocol with the title of *"Does colorectal positive contrast administration per rectum contribute to the emergent diagnostic accuracy of computed tomography (CT) for identifying colorectal injury in patients with penetrating torso injury?"* for the time period as specified has already been performed and based on the lack of adequate patient numbers permission to submit a new protocol for this study population has been requested.

Data analysis:

The researcher will type data into Excel for analysis by Department of Biostatistics, UFS. Results will be summarised by frequencies and percentages (categorical variables) and means, standard deviations or percentiles (numerical variables) with 95% confidence intervals for main outcomes. Contingency tables will be used to calculate sensitivities and specificities, and to compare these in subgroups using appropriate hypothesis testing and 95% confidence intervals for differences in percentages. Logistic regression will be performed to identify combinations of factors which have sensitivity and specificity.

Implementation:

Determining sensitivity and specificity of certain factors, or combination of factors, for indicating the presence of GIT injury and the subsequent need for LAP with the aim of

assisting in limiting the number of possible negative laparotomies in patients with penetrating torso trauma while also limiting the number of false positive CT scans.
Limiting the initial CT evaluation of penetrating torso trauma to IVI contrast study only (excluding the addition of colorectal contrast) in order to save time and radiation to the patient if the other direct and indirect signs of large bowel injury have an acceptable sensitivity and specificity for diagnosing colorectal injury.

Time schedule:

Submission to the Health Science Research Ethics Committee for approval January 2020
Submission to the Free State department of Health for approval in March 2020
Data collection April 2020
Statistical analysis May 2020
Writing article June 2020
Submission to the journal June 2020

Budget

Additional R500 for petrol to drive to Pelonomi to retrieve additional patient information

- Costs will be carried by the researcher

Ethical aspects:

1. Obtain ethical approval from the Health Science Research Ethics committee of the University of the Free State
2. Patient consent waived as it is a retrospective study with anonymized use of patient information without the possibility of the study impacting the management or outcome of the patient population that will form part of the study
3. Confidentiality will be maintained by:
    - Patient identifying information will be anonymized by assigning consecutive numbers to each patient.
    - Only Dr Biddulph will be aware of patient identifying information in order to obtain the necessary information from the patient's medical and imaging records.
    - The anonymized information will be documented on a data sheet and the data sheet will be handed in for statistical analysis.
    - The anonymized information and statistical analysis results will be used in the final article for publication
    - Patient information will be reviewed at designated radiology reporting stations or on designated computers used for patient electronic record keeping

There are no conflicts of interest

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Electronic data form used for data capturing

Study Number	Age	Gender	Single (S) or Multiple (M) penetrating injuries	Gun shot wound (GSW) (Yes/No)	Stab wound (Yes/No)	Region(s) involved: TA, A, B, P, F	Left (L) or right (R) of the midline; Midline (M)	Anterior (TA + A)	Back left (L) or right (R)	Flank Left (L) or right (R)	Pelvis	Pelvis gunshot wound (GSW) or stab (S)	Rectal contrast given. Yes/No
1													
2													
3													
4													

Table 1

Bullet fragments within bowel lumen (Yes/No)	Colon wall thickening (Yes/No)	Penetrating wound trajectory toward colon(Yes/No)	Clear path up to wall (Yes/No)	Soiling adjacent to the colon (Yes/No)	Colon injury found during explorative laparotomy (Yes/No)	Location of injury found during surgery	Trajectory to small bowel (Yes/No)	Clear tract (Yes/No)	Small bowel wall thickening (Yes/No)	Small bowel luminal disruption (Yes/No)	Abnormal small bowel enhancement (Yes/No)

Mesenteric fat stranding close to bowel loops (Yes/No)	Mesentric haematoma (Yes/No)	Mesenteric contrast extravasation (Yes/No)	Interloop fluid (Yes/No)	Surgical small bowel perforation (Yes/No)	Tract trajectory to stomach (Yes/No)	Clear tract (Yes/No)	Wall thickening (Yes/No)	Wall disruption (Yes/No)	Gastric penetrating injury at surgery (Yes/No)	Intra- abdominal fluid at a site distant to injury (Yes/No)

Segment to which contrast has reached and whether optimal (O) opacification and distension or suboptimal (S) [if either distension or opacification is not optimal]	Rectum [Optimal (O) or Suboptimal (S)] or No opacificatio n [N]	Sigmoid colon [Optimal (O) or Suboptimal (S)] or No opacificatio n [N]	Descending colon [Optimal (O) or Suboptimal (S)] or No opacification [N]	Splenic flexure [Optimal (O) or Suboptimal (S)] or No opacificatio n [N]	Transverse colon [Optimal (O) or Suboptimal (S)] or No opacification [N]	Hepatic flexure [Optimal (O) or Suboptimal (S)] or No opacification [N]	Ascending colon [Optimal (O) or Suboptimal (S)] or No opacification [N]	Caecum [Optimal (O) or Suboptimal (S)] or No opacificatio n [N]	Optimal contrast opacification up to the descending colon (L) or ascending colon (R)	SubOptimal contrast opacification up to the descending colon (L) or ascending colon (R	Contrast leak (Yes/No)	Colon wall disruption (Yes/No)

Solid organ injury (Yes/No)	Subdiaphragmatic free air on X-rays (Yes/No)	Intraperitoneal free air at a site distant to the tract (Yes/No)	Reporting registrar suspected GIT injury: yes (Y), no (N), uncertain (U)	Discharged after a minimum of 24 hrs serial examinations without suspected bowel injury (Yes/No)

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South African Journal of Radiology- Author guideline

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Word limit - **3000 words** (excluding the structured abstract and references)
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List of abbreviations

CT	Computed tomography
EAST	Eastern Association for the Surgery of Trauma
GIT	Gastrointestinal tract
GSW	Gun shot wound
LAP	Explorative laparotomy
N-LAP	Non-therapeutic laparotomy
SCE	Serial clinical examination
SNOM	Selective non-operative management
SW	Stab wound
WTA	Western Trauma association