OUTCOMES OF FAILURE OF SELECTIVE NON-OPERATIVE MANAGEMENT OF PENETRATING ABDOMINAL TRAUMA

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DECLARATION

I, Naser Almgla, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university. I empower the university to reproduce for the purpose of research either the whole or any portion of the contents in any manner whatsoever.

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DR NASER ALMGLA

Signed on the 12th day of February 2022

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LIST OF TABLES AND FIGURES

ABBREVIATIONS

ASIS	anterior superior iliac spine
CD	Clavien-Dindo
CT	computed tomography
DOM	delayed operative management
GSH	Groote Schuur Hospital
GSHTC	Groote Schuur Hospital Trauma Centre
GSW	gunshot wound
ICS	intercostal space
LOS	length of stay
NL	negative laparotomy
NOM	non-operative management
NTL	non-therapeutic laparotomy
PAT	penetrating abdominal trauma
SA	South Africa
SNOM	selective non-operative management
SW	stab wound
UNODC	United Nations Office on Drugs and Crime
g/dL	Gram per decilitre

DEFINITIONS

ABDOMINAL ANATOMY

Anterior abdomen: This area extends from the costal margin superiorly to the symphysis pubis and inguinal ligaments inferiorly, and between the anterior axillary lines laterally. The region below the anterior superior iliac spine (ASIS) line is the abdomino-pelvic area. The anterior abdomen is further divided into nine regions by the longitudinal right and left midclavicular lines, and transverse subcostal and interspinous planes. Thus, the regions defined are the right and left iliac, hypogastric, right and left flank, umbilical, right and left hypochondrial and epigastric.

Flank region: This is the area between the anterior and posterior axillary lines, extending from the costal margin to the anterior superior iliac crest.

Thoracoabdominal region: This area extends from the fourth intercostal space anteriorly and the seventh Intercostal space (ICS) posteriorly to the costal margin.

Back region: This area extends from the tip of the scapula or the seventh ICS to the iliac crest, posterior to the axillary lines.

LAPAROTOMY

Laparotomy in this study was defined as therapeutic if an intra-operative injury was identified and repaired. Unnecessary laparotomy refers to both negative laparotomy (NL) and nontherapeutic laparotomy (NTL), when no intra-abdominal injury and no surgical intervention was required for an injury, respectively.

ABSTRACT

Background: Selective nonoperative management (SNOM) of penetrating abdominal trauma (PAT) is routine at our centre. The aim of this observational study is to report the outcomes of patients who have failed SNOM.

Methods: All patients for the period (May 2015 – January 2018) who presented with penetrating abdominal trauma were reviewed. The patients were categorised into two groups: immediate laparotomy and delayed operative management (DOM) groups. The outcomes of the two groups were compared in terms of postoperative complications as a primary outcome, mortality and length of hospital stay as secondary outcomes.

Results: A total of 944 patients with PAT were managed over the 33-month study period. After excluding 100 patients undergoing damage control surgery; 402 (47.6%) and 542 (52.4%) patients were treated with SNOM and immediate laparotomy, respectively. In the NOM cohort, 359 (89.3%) were managed successfully without laparotomy. Thirty-seven (86.0%) patients in the DOM group had a therapeutic laparotomy and six (14.0%) had an unnecessary laparotomy. Nine (20.9%) patients in the DOM group developed complications. There was no significant difference in the complication rates between the immediate laparotomy and DOM group. The hospital length of stay (LOS) was comparable between the two groups. There was no mortality reported in the SNOM group.

Conclusion: Delayed laparotomy for PAT in patients initially selected for NOM, irrespective of mechanism, results in morbidity, mortality and hospital stay comparable to those who underwent immediate laparotomy.

LITERATURE REVIEW

Background

South Africa (SA) has one of the most violent societies worldwide. According to the United Nations Office on Drugs and Crimes (UNODC) global study on homicide (2013), Southern Africa and Central America had the highest homicide rates globally, four times the world average (1). Penetrating abdominal trauma (PAT) contributes significantly to the burden of injuries manged by all major trauma centres nationally; This has placed further pressure on an already resource-limited health care system (2).

Penetrating abdominal trauma is defined as a violation of the peritoneal cavity; the most common aetiologies are stab (SW) and gunshot wounds (GSW). The approach to and the management of PAT has evolved drastically over the last century. Interestingly, penetrating abdominal trauma had been previously managed expectantly due to a lack of suitable anaesthesia, antibiotics, and imaging capabilities. After the first and second world wars, mandatory exploration for PAT became standard of care (3–5). More recently, there has been paradigm shift from mandatory laparotomy strategy to a more conservative approach, in part due to the high incidence of non-therapeutic laparotomies seen in many trauma centres (5–7). Non-therapeutic laparotomy (NTL) is potentially associated with significant morbidity; reported complications include ileus, thromboembolic events, wound infection, incisional hernia, and adhesive bowel obstruction (8–11).

In the 1960s, Shaftan (1960) and Stein *et al.* (1968) postulated that PAT could be managed non-operatively in selected patients without increased morbidity and mortality (8,12,13). Recent data suggest that selective NOM is safe, cost-effective and reduces NTL rates (8,10–

12,14–17). Despite this evidence, SNOM remains a controversial. There are ongoing concerns regarding the post-operative outcomes in patients failing SNOM. The perception is that delayed operative management (DOM) results in worse outcomes. In a large review of the North American Trauma Database, Zafar *et al.* showed that unsuccessful SNOM leads to increased morbidity and mortality in patients with SWs and GSWs to the abdomen compared to those who underwent successful SNOM (18). However, In a recent systematic review by Lamb *et al.*, SNOM was shown to be safe in patients who sustained GSW to the abdomen (19).

Indications for immediate laparotomy include haemodynamic instability, peritonitis, blood per rectum, radiological evidence supportive of internal injury and visceral evisceration. In addition, an immediate laparotomy would be indicated where patients have sustained head injury resulting in a depressed level of consciousness or spinal cord injury that result in denervation of the abdominal wall. The current literature supports SNOM in patients who do not satisfy the aforementioned indications for an immediate laparotomy.

Anatomical considerations

A thorough understanding the anatomy of the abdominal cavity and its contents is essential in the management of PAT. Briefly, the surface anatomy of the abdomen is divided into four anatomical regions namely the anterior abdomen, flank region, thoracoabdominal and back region. In the abdominal cavity, both the peritoneal cavity and retroperitoneal spaces are of importance. Internal organs are either extra- or intraperitoneal and further divided into solid and hollow viscus organs. Timeous recognition of retroperitoneal injuries remains challenging as patients may not present with any signs and symptoms on initial clinical evaluation. For this reason, penetrating trauma to the back and flank must be evaluated carefully to rule out any retroperitoneal injury (20).

The thoracic cage covers the upper part of the abdominal cavity. This part represents the thoracoabdominal component of the abdominal cavity. Penetrating trauma to the lower chest can cause injury to the diaphragm and intra-abdominal organs. However, evidence suggests that left thoracoabdominal injuries are associated with more clinically significant diaphragmatic injuries when compared to thoracoabdominal injuries on the right. Thus, many have advocated SNOM for patients presenting with right-sided thoracoabdominal injuries; it is considered feasible, safe, and effective regardless of the severity of liver injury (21–23). On the other hand, left-sided thoracoabdominal injuries will often warrant diagnostic laparoscopy after initial SNOM to exclude any diaphragmatic injury (24).

Mechanism of injury

The mechanism of injury provides essential information in predicting injury patterns and subsequent severity. Gunshot wounds are often associated with more destructive injuries and higher morbidity and mortality. Whilst SNOM is regarded safe in patients with SWs, its use in patients who have sustained GSWs has raised many concerns.

Compared to abdominal SWs, SNOM for abdominal GSW has not been widely accepted, due to an increased rate of significant intra-abdominal injuries (25). Dawidson *et al.* reviewed 277 patients with GSWs to the abdomen over five years, and showed that 86% of the patients had intra-abdominal injuries, and the reported NTL rate was 14% (25). However, in the last few decades, the concept of mandatory laparotomy for gunshot abdomen has become less prescriptive. Demetriades *et al.* (1997) and Velmahos *et al*. (2001) published a series of prospective studies that showed that GSWs to the abdomen could be managed safely without operative exploration in selected patients. Their figures suggest that SNOM would be

successful in one-third of patients with GSW to the anterior abdominal wall and two-thirds of patients with GSW to the back (26–28). In keeping with international findings, a local study by Navsaria *et al.* demonstrated that SNOM of GSW to solid organs (liver and kidneys) is a feasible and safe option in selected patients with no hard signs and after careful evaluation using CT scan (22,29).

Failed non-operative management

For those patients who failed SNOM, delayed surgical management is required. Currently, there is a concern that failed SNOM and delayed surgical treatment might be associated with higher morbidity and mortality rates. There exists considerable divergence of opinions amongst surgeons. As mentioned previously, Zafar *et al*. reported increased mortality in patients after failed SNOM (18). However, another study reporting on SNOM of GSWs showed no difference between outcomes in patients who underwent delayed laparotomies and those selected for an immediate laparotomy (19). In this regard, Peev *et al.* suggest that delayed surgical treatment in patients who failed SNOM does not increase mortality or morbidity if performed in a structured protocol (30). A more recent review of the management of 6777 GSWs, supports the notion that SNOM is sound clinical practice (31). Despite advancements towards a more conservative approach, few studies have evaluated the outcomes of SNOM.

The primary aim of this study was thus to compare postoperative complications between patients undergoing immediate laparotomy vs delayed operative management after presenting with PAT at a tertiary hospital in South Africa. In addition, we assessed mortality and length of hospital stay between these two subgroups.

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OUTCOMES OF FAILURE OF SELECTIVE NON-OPERATIVE MANAGEMENT OF PENETRATING ABDOMINAL TRAUMA

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ABSTRACT

Background: Selective nonoperative management (SNOM) of penetrating abdominal trauma (PAT) is routine at our centre. The aim of this observational study is to report the outcomes of patients who have failed SNOM.

Methods: All patients for the period (May 2015 – January 2018) who presented with penetrating abdominal trauma were reviewed. The patients were categorised into two groups: immediate laparotomy and delayed operative management (DOM) groups. The outcomes of the two groups were compared in terms of postoperative complications as a primary outcome, mortality and length of hospital stay as secondary outcomes.

Results: A total of 944 patients with PAT were managed over the 33-month study period. After excluding 100 patients undergoing damage control surgery; 402 (47.6%) and 542 (52.4%) patients were treated with SNOM and immediate laparotomy, respectively. In the NOM cohort, 359 (89.3%) were managed successfully without laparotomy. Thirty-seven (86.0%) patients in the DOM group had a therapeutic laparotomy and six (14.0%) had an unnecessary laparotomy. Nine (20.9%) patients in the DOM group developed complications. There was no significant difference in the complication rates between the immediate laparotomy and DOM group. The hospital length of stay (LOS) was comparable between the two groups. There was no mortality reported in the SNOM group.

Conclusion: Delayed laparotomy for PAT in patients initially selected for NOM, irrespective of mechanism, results in morbidity, mortality and hospital stay comparable to those who underwent immediate laparotomy.

INTRODUCTION

Penetrating abdominal trauma (PAT) is an endemic health care problem in South Africa. Southern Africa and Central America have the highest homicide rates, four times the global average (1). As a result, the management of trauma in general and specifically PAT continues to represent a considerable burden on the local healthcare systems. The management of PAT has evolved over the last five decades from routine mandatory laparotomy to selective non-operative management (SNOM). Selective non-operative management has been embraced as a safe alternative for stab wounds (SW) to the abdomen since the initial reports by Shaftan (1960) and Stein (1968) (2–4). More recently, large studies from South Africa by Muckart et al in 1990 and Demetriades et al in 1991 suggested that SNOM can be applied safely to a specific group of patients with gunshot wound (GSW) to the abdomen (5,6). Since then the SNOM of GSW started to gain momentum as an acceptable treatment strategy. Despite accepting SNOM as a routine practice for PAT in high-volume trauma centers, there is a paucity of reports of the outcomes of unsuccessful SNOM. A better understanding of this particular group is required to guide an effective and safe approach for patients with PAT, especially those selected for SNOM. This study aims to investigate the outcomes (complications and mortality) of unsuccessful SNOM or, as previously more appropriately termed by our group, delayed operative management (DOM) (7,8).

METHODOLOGY

Participants

The present study was approved by the Human Research Ethics Committee of the University of Cape Town (HREC 770/2017). This was a single centre observational study of all patients presenting with PAT to the Groote Schuur Hospital Trauma Centre (GSHTC) in Cape Town,

South Africa during the period May 2015 to January 2018. Patients were managed according to established GSHTC protocols for PAT (7–9).

Pre-operative variables

Patient characteristics, vital signs, trauma severity scores, and clinical findings were recorded according to standard protocols. The indications for immediate laparotomy include hemodynamic instability and peritonitis. The protocol is modified for patients presenting with blood per rectum, evisceration, and CT findings suggestive of hollow visceral injury (free/loculated air, free fluid, bowel wall edema and mesenteric stranding) (10,11). CT scans were indicated in patients presenting with haematuria and/or right upper quadrant missile trajectory to exclude urinary tract and liver injury. In the presence of haematuria, where trajectory traversed the pelvis, a CT cystogram was performed. CT scan is also indicated when there is uncertainty of whether a suspected tangential bullet trajectory has breached the peritoneal cavity or not. Patients presenting with PAT who did not satisfy the above indications for immediate laparotomy were selected for a trial of SNOM.

Non-operative management

Patients selected for NOM were admitted to the trauma high care ward. These patients underwent continuous monitoring and clinical examinations. Oral intake was introduced after 24 hours of uneventful observation. A patient was discharged once able to tolerate a normal diet with an abdominal injury form indicating the warning signs for immediate return. Patients selected for NOM with increasing abdominal tenderness, hemodynamic instability, or suspected intra-abdominal sepsis underwent delayed operative management (DOM).

Operative management

Delayed operative management refers to any surgical intervention after an initial decision for NOM regardless of time. In the present study, a laparotomy is defined as therapeutic if intra-operative injuries were identified and repaired. Where no intra-abdominal injuries were identified, laparotomies were considered as negative laparotomies (NL). Non-therapeutic laparotomies (NTL) refers to injuries confirmed on laparotomy not requiring any intervention.

Data management and analysis

Statistical computations were made using RStudio (RStudio Team, 2021. RStudio: Integrated Development Environment for R, Boston, MA) (12). Statistical significance was set at $p < 0.05$. Categorical data were reported as numbers and percentages, and groups were compared using a Pearson's chi-square (χ 2) test. Continuous data reported as median and interquartile range (IQR), and median with 95% confidence interval, with groups compared using Wilcoxon test and student t-test respectively.

RESULTS

After excluding 100 patients who underwent damage control surgery at the index laparotomy, a total of 844 patients with PAT were managed over the 33-month study period. Of these, 402 (47.6%) were initially selected for SNOM and the remaining 442 (52.4%) underwent immediate laparotomy. Of the 402 patients selected for NOM, 359 (89.3%) were managed successfully without laparotomy, and the remaining 43 (10.7%) underwent DOM. Of 442 patients who underwent immediate laparotomy, 399 (90.3%) underwent a therapeutic laparotomy, and 43 (9.7%) patients had either negative or non-therapeutic laparotomy; 20 (4.5%) and 23 (5.2%), respectively. The treatment pathways and mechanism of injury are illustrated in Figure 1.

The immediate laparotomy and DOM groups were compared for patient demographics, mechanism of injury, trauma severity scores, admission vital signs, biochemical results, and abdominal clinical findings (Table 1). There were no differences in the patient age, demographics, hemodynamic stability, hemoglobin levels, and the need for blood transfusion in the emergency department between the two groups. As expected, the mechanism of injury was more distributed towards GSW in the immediate laparotomy group. The patients in the immediate laparotomy group presented higher trauma scores than the SNOM group. However, there was no significant difference in the number of patients presenting with GSW and SW in the DOM group, 20 (46.5%) with GSW and 23 (53.5%) with SW.

As far as the indications for surgical inventions are concerned, we observed that increasing abdominal tenderness with new peritonitis, adjunct radiological study results, as well as clinical and investigational features of sepsis constituted the primary indications for laparotomy in 37.2%, 32.6% and 25.6% of the DOM group, respectively. In contrast, peritonitis was by far the most common indication for surgery in the immediate laparotomy group, followed by radiological findings and hemodynamic instability (Table 2). However, two patients in the SNOM group became hemodynamically unstable. The first patient was referred with a single GSW to the lower left-back. CT scan demonstrated a grade IV splenic laceration with minor hemoperitoneum. A day later, the patient dropped his haemoglobin from 10 g/dl to 7 g/dl with compensated shock. The patient went for DOM and had a splenectomy. The second patient presented with GSW to the right flank. CT scan showed grade II liver and right kidney injuries. The patient underwent DOM after a significant drop in the haemoglobin to 8 g/dl with compensated shock. He had non-therapeutic laparotomy with findings consistent with the CT findings, and no hollow organ injury was identified.

Time in hours from admission to surgery was significantly longer in the DOM patients (Table 2). The median delay from the admission to surgery in the DOM group was 32 (IQR 25-61) hours. This time interval was significantly longer compared to the immediate laparotomy group, where most of the patients went to theatre within five hours of admission (p=0.001). Three-hundred and ninety-nine (90.3%) patients underwent immediate laparotomy with therapeutic interventions. The remaining 43 (9.7%) had a negative or non-therapeutic laparotomy, 4.5% and 5.2%, respectively. Thirty-seven (86.0%) patients in the DOM group had a therapeutic laparotomy, and six (14.0%) had an unnecessary laparotomy, of which three (7.0%) were negative and three (7.0%) were non-therapeutic. Hollow viscus perforation was found in 355 (79.8%) patients in the immediate laparotomy group and 24 (55.8%) in the DOM group. The small bowel was the most frequently injured organ in the immediate laparotomy group, followed by the colon. Ten (23.3%) patients in the DOM group had a colon injuries as the most frequently injured organ. A detailed description of the intraoperative findings is summarized in Table 3.

The distribution of the wound location between the two groups was not significant (p=0.39). Most immediate laparotomy patients sustained a penetrating injury to the anterior abdomen or left flank, 28.1% and 21.8%, respectively. Most DOM patients sustained a penetrating injury to the left flank region 28.6%. The wound location and detailed description for both groups are shown in Table 4.

There was no significant difference in both major and minor complications using the Clavien-Dindo classification (CD) between the two groups. Major complications (CD III and IV) were observed in three patients and minor complications (CD I and II) in six patients. The secondary outcome of mortality showed 6.3% deaths in the immediate laparotomy group and no deaths

in the DOM group. Table 5 summarizes the outcomes, including deaths, complications and ICU and hospital LOS. Detailed description of the complications in the nine patients undergoing DOM is presented in Table 6.

DISCUSSION

The management of PAT has evolved and undergone substantial paradigm shifts over the last century. In view of the low mortality rate associated with unnecessary laparotomies and the perceived potential morbid outcomes associated with DOM, the opponents of SNOM swear to a philosophy of "look and see" rather than "wait and see" for PAT, specifically for GSW in low volume trauma centers (2,13,14).

Despite the excellent results with a reduction in mortality from 50.0% to 7.0%, with the implementation of a routine laparotomy policy for PAT during World Wars I and II, the emergence of SNOM was a groundbreaking change in the management of civilian PAT (2,3,13,15,16) SNOM adoption for SW to the abdomen started in centers with high patient volume. In the 1960s, Shaftan (1960) and Stein & Lissoos (1968) introduced the SNOM strategy after mandatory laparotomy had been the mainstay of treatment for decades (2–4,17). In the Shaftan study, 125 (69.4%) patients were managed non-operatively, resulting in mortality rates of less than 1.0% (3). In Stein's and Lissoos series of 340 patients, they demonstrated a selective approach in 150 (35%) patients, with a SNOM success rate of 87.0% (2). Furthermore, Nance *et al*. concluded that the mandatory exploration policy for all SWs of the abdomen was associated with unnecessary laparotomy in two-thirds of the patients, whereas allowing surgical judgment in deciding for surgical or non-surgical management was associated with reducing this number to less than half. SNOM also reduced the overall

complication rate from 27.0% to 12.0% and an average period of hospitalization from 7.9 to 5.4 days (18). Since these landmark studies, many others have supported the new strategy with similar findings; significantly lower unnecessary laparotomy rates, lower overall complication rates, and lower costs were observed with the NOM strategy (19–23).

In 1986 Friedmann *et al.* reported that SNOM is not associated with increased mortality and morbidity, and the unnecessary laparotomy rate would be 70% in the non-operative group if they went for routine laparotomy after SW injury to the abdomen (19). In 1987 a prospective study of 651 patients with SW to the abdomen by Demetriades *et al*. showed that mandatory laparotomy would have resulted in a non-therapeutic laparotomy rate of 45.0% (24). Another study by the same author in 1988 showed that for patients who sustained stab wounds to the back, only 15.0% resulted in clinically significant injuries (25). Some studies reported DOM rate ranges between 10% to 20% (26–28). Despite the low mortality rate associated with the unnecessary laparotomy, it was not a benign intervention. Reported complication rates were between 2.5% to 41.0%, and included sepsis, postoperative ileus, and pneumonia (3,18,22,23,29). Additionally, long term complications such as incisional hernia and small bowel obstruction are also documented (23,30). In the current study, 70.2% of the patients with SW to the abdomen were selected for NOM with a 90,1% success rate, and 9.9% underwent DOM, which is comparable with our previous rates (26).

Unlike abdominal stab wounds, SNOM for abdominal GSW has not gained full acceptance and has faced initial resistance due to the higher rate of intra-abdominal injuries (31,32). Dawidson *et al.* reviewed 277 patients with GSWs to the abdomen over five years and showed that as high as 86.0% of the patients had intra-abdominal injuries and reported a non-therapeutic laparotomy rate of 14% (31). However, in the last few decades, the concept of

mandatory laparotomy for gunshot wounds to the abdomen has become less dogmatic. Demetriades *et al.* (1997) and Velmahos *et al*. (2001) published a series of prospective studies that showed that GSW to the abdomen could be managed safely without operative exploration in selected patients. Their figures suggest that SNOM would be successful in one-third of patients with GSW to the anterior abdomen and two-thirds of patients with GSW to the back (33,34).

Similarly, in this study, 33.0% of patients presenting with GSW to the abdomen were selected for NOM. The success rate was 88.2%, and the delayed operative rate was 11.8%, within the range observed in the literature (28,35,36). In addition, Navsaria *et al*. had previously demonstrated that SNOM of GSW to solid organs (liver and kidneys) is a feasible and safe option in selected patients with no peritoneal signs and after a careful evaluation with CT scan (9,35,37,38).

DOM is perceived to be associated with increased morbidity and mortality, despite the undeniable benefits of SNOM implementation for PAT. SNOM found to have reduced negative laparotomy rates, reduced overall complication, reduced LOS, and reduced costs in both SW and GSW to the abdomen(27,39,40). In a prospective review by our group of 1106 patients with GSW to the abdomen, 272 (24.6%) were selected for SNOM, and only 13 patients underwent delayed laparotomy with a success rate of 95.2% (35).

Currently, there is a concern that failed SNOM and delayed surgical treatment might be associated with higher morbidity and mortality rates. There is considerable divergence of opinions between different authors. Zafar *et al.* (2011) reviewed the outcome of SNOM of PAT from the North America national trauma database and found that SNOM is generally

successful; however, its failure is associated with increased mortality compared to the successful non-operative group (28). On the other hand, a systematic review by Lamb *et al*. in 2014 included more than 18,000 patients with abdominal GSW; 32.2% of the patients underwent SNOM. Of these patients, 15% underwent delayed laparotomy. They observed that the delayed laparotomy group had similar outcomes to the immediate laparotomy group (41). Similarly, Peev *et al*. stated that delayed surgical treatment in patients who failed SNOM for PAT does not cause unnecessary mortality or morbidity if performed in a structured protocol (42). Furthermore, a more recent systematic review in 2018 by Al Rawahi *et al*. analyzed 6777 patients who underwent SNOM after GSW to the abdomen and concluded that non-operative management is safe (36). Table 7 summarizes the most recent large series of penetrating abdominal trauma.

SNOM is a dynamic process; it starts with the appropriate selection of the patient for NOM, followed by close observation and serial clinical examination. Should the patient develop a change in abdominal signs or features suggestive of intra-abdominal sepsis or hemodynamic instability, the patient should be considered for a delayed laparotomy (43). In the current study, the DOM rate was 10.7%, with 7.0% negative and 7.0% NTL rates, which is similar to previous studies (28,39) This study showed that outcomes including; complications, mortality and hospital length of stay (LOS) in patients with PAT are no different in patients undergoing DOM compared to patients undergoing immediate laparotomy (Table 5 and 6). We included both SW and GSW in our analysis as we believe that the principles of selective conservative management hold true in both GSW and SW to the abdomen, and the treatment algorithm should be the same as we demonstrated in our recent study (8).

CONCLUSION

Delayed laparotomy for PAT in patients initially selected for NOM, irrespective of mechanism, results in comparable morbidity, mortality, and hospital stay to those who underwent immediate laparotomy.

Table 1. Patients demographics, injury severity scores, presenting features, and injury profile.

VARIABLES		IMMEDIATE LAPAROTOMY (n=442)	FAILED SNOM (n=43)	*p*-VALUE
Patient demographics	**Age:** median (IQR)	27 (22-30)	30 (22.5-36)	NS
	Gender:			
	Male: N (%)	416 (94%)	38 (88.4%)	NS
	Female: N (%)	26 (5.9%)	5 (11.6%)	
Injury characteristics: N (%)	GSW	343 (77.6%)	20 (46.5%)	**<0.001**
	SW	99 (22.4%)	23 (53.5%)	
Trauma scores: Median (IQR)	PATI Score	8.5 (4-19)	6 (3-11.2)	NS
	AIS Abdomen	3 (3-4)	3 (1-3)	**<0.001**
	Revised Trauma Score	7.84 (7-7.8)	7.84 (7-7.8)	NS
	ASA Score	1 (1-2)	1 (1-2)	NS
	Kampala Score	14 (14-15)	14 (14-15)	NS
Admission characteristics:	Systolic BP	131 (129-133)	131 (124-138)	NS
Mean (CI 95%)	HR	95 (93-96)	90 (85-95)	NS
	pH	7.3 (7.3-7.3)	7.40 (7.3-7.34)	NS
	Lactate	2.8 (2.6-3)	1.9 (1.6-2.2)	**<0.001**
	Haemoglobin	12.2 (12-12.5)	12.4 (11.9-13)	NS
	Bicarbonate	21 (20.7-21.3)	22.3 (21.1-23.4)	**0.02**
Haemodynamic stability: N (%)	Responder	54 (9.5%)	2 (4.7%)	NS
	Stable	368 (82.9%)	41 (95.3%)	
	Unstable	22 (5%)	0 (0%)	
Evisceration: N (%)	Omentum	24 (5.4%)	4 (9.3%)	
	Visceral	31 (7%)	0 (0%)	NS
Blood transfusion: N (%)	PRBC*	42 (9.5%)	3 (7%)	NS

Continuous variables reported as median (interquartile range) with categorical data reported as number (percentage). SNOM: selective nonoperative management; IQR: interquartile range. GSW: gunshot wound; SW: stab wound; PATI: penetrating abdominal trauma index; AIS: abbreviated injury scale; ASA: American society of anesthesiologists; BP; blood pressure; HR: hear rate; pH: potential of hydrogen; PRBC; packed red blood cells.

Table 2. Summary of the indications for laparotomy.

INDICATIONS, n (%)	**IMMEDIATE LAPAROTOMY (n=442)**	**FAILED SNOM (n=43)**	***p*-VALUE**
Peritonitis	298 (67.4%)	16 (37.2%)	**< 0.001**
Radiology findings	72 (16.3%)	14 (32.6%)	NS
Hemodynamically unstable	19 (4.3%)	2 (4.7 %)	NS
Unreliable physical examination	22 (5%)	0	NS
Evisceration	31 (7%)	0	NS
Concern of sepsis	0	11 (25.6%)	**< 0.001**
Delay to OR in hours, median (IQR)	5 (2 – 8)	32.5 (25.25 – 61.5)	**<0.001**

Continuous variables reported as median (interquartile range) with categorical data reported as number (percentage). SNOM: selective nonoperative management; IQR: interquartile range.; OR: operating room.

Table 3. Laparotomy results and intraoperative findings.

INTRAOPERATIVE FINDINGS		**IMMEDIATE LAPAROTOMY (n=442)**	**DOM (n=43)**	***p*-VALUE**
RESULTS OF SURGERY,	Negative	20 (4.5 %)	3 (7 %)	
n (%)	Non-therapeutic	23 (5.2 %)	3 (7 %)	NS
	Therapeutic	399 (90.3 %)	37 (86 %)	
TYPE OF ORGAN INJURY,	Organ perforation	355 (79.8 %)	24 (55.8 %)	**<0.0001**
n (%)	Stomach	88 (19.8 %)	7 (16.3%)	**<0.001**
	Small bowel	208 (46.7 %)	6 (14 %)	**<0.0001**
	Colorectal	156 (35.1 %)	10 (23.3 %)	**<0.001**
	Liver	73 (16.4 %)	1 (2.3 %)	**<0.001**
	Spleen	39 (8.8 %)	3 (7 %)	**<0.001**
	Kidney	24 (5.4 %)	2 (4.7 %)	**<0.001**
	Urinary bladder	31 (7%)	1 (2.3%)	**<0.001**
	Pancreas	14 (3.1%)	1 (2.3%)	**<0.001**
	Ureter	9 (2%)	1 (2.3%)	**<0.001**
	Diaphragm	67 (15.1 %)	5 (11.6 %)	**<0.001**

Data reported as number (percentage). SNOM: selective nonoperative management.

Table 4. Penetrating trauma wound location in the immediate laparotomy and failed NOM group.

WOUND LOCATION N (%)	IMMEDIATE LAPAROTOMY (n=442)	FAILED SNOM (n=43)	p-VALUE
Thoracoabdominal left	99 (16.3 %)	11 (15.9 %)	SN
Thoracoabdominal right	67 (11.0 %)	5 (7.9 %)	
Flank left	133 (21.8 %)	18 (28.6 %)	
Flank right	85 (14.0 %)	10 (15.9 %)	
Anterior	171 (28.1 %)	11 (17.5 %)	
Pelvis	54 (8.9 %)	8 (12.7 %)	

Data reported as number (percentage). SNOM: selective nonoperative management.

Table 5. Post-operative outcomes.

OUTCOME, N (%)	**IMMEDIATE LAPAROTOMY (n=442)**	**DOM (n=43)**	**p-VALUE**
Death	28 (6.3%)	0 (0 %)	**< 0.001**
Complications			
Minor complications*	48 (10.8%)	6 (13.9%)	NS
Major complications**	74 (16.7%)	3 (6.9%)	NS
ICU LOS, median (IQR), days	3 (2-4)	2 (0)	NS
Hospital LOS, median (IQR), days	7 (5-12)	8 (6-11)	NS

* Clavien-Dindo I-II; ** Clavien-Dindo III-IV; ICU: Intensive care unit; LOS: length of stay; IQR: interquartile range.

Table 6. Summary of patients with delayed operative management complications

PATIENT	GSW/SW	HOURS FROM INJURY TO OR	ORGAN INJURED	COMPLICATION	CD SCORE	REINTERVENTION	ICU LOS	TOTAL LOS
1	SW	57	Spleen/diaphragm laceration	ileus	II	No	No	15
2	GSW	96	Splenic flexure colon injury	Early necrotising fasciitis of GSW track	IIIb	Yes	No	14
3	SW	120	Hemoperitoneum, serosal tear of transverse colon and terminal ileum	No complication of DOM. However, the patient was discharged and returned with incarcerated omentum and hemoperitoneum	-	No	No	5
4	GSW	24	Pelvic hematoma	ileus	II	No	No	9
5	GSW	89	Small bowel and descending colon injury (SB resection and primary anastomosis and left hemicolectomy and stoma)	Stoma creation because of the delay	I	No	No	11
6	GSW	16	Small bowel and intraperitoneal rectal injury Had repair and loop colostomy	Small bowel obstruction secondary to parastomal hernia	IIIb	Relook for SBO	No	18
7	GSW	63	Pseudoaneurysm and right renal artery-IVC fistula. Grade II liver laceration Had nephrectomy and patch repair of the IVC injury	IVC thrombosis AKI Ileus	IV	No	2	19
8	GSW	26	Grade IV splenic injury and grade I pancreatic tail injury	Readmission day 13 post-operative with ileus and mild acute pancreatitis	II	No	No	8+3
9	SW	53	Grade II laceration of the left kidney	UTI	II	No	No	8

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Table 7. Results of penetrating abdominal trauma from the large series in the last three decades

	TOTAL NUMBER OF PATIENTS, n (SW/GSW)	NUMBER OF SNOM IN SW	NUMBER OF SNOM IN GSW	UNNECESSARY LAPAROTOMY IN THE IMMEDIATE LAPAROTOMY SW/GSW	NUMBER OF DOM IN SW: GSW	UNNECESSARY LAPAROTOMY IN THE DOM SW/GSW	DOM MORBIDITY IN SW: GSW	DOM DEATHS IN SW: GSW
Demetriades *et al.*1991 (6) GSW anterior abdomen	146 (0/146)	N/A	41(28.0%)	6 (5.7%), 1 NTL and 5 negative laparotomies	0:7 (17.1%)	0	0:2 (33.3%) SSI	0:0
Demetriades *et al.*1997 (33) GSW anterior abdomen	309 (0/309)	N/A	106 (34.3%)	20 (10.8%), 4 NTL and 16 negative laparotomies	0:14(13.2%)	9 (64.2%), 2 NTL and 7 negative laparotomies	0:2 (14.3%) Psoas abscess and ARDS	0:0
Velmahos *et al.* 1997 (34) GSW to the back	188 (0/188)	N/A	130 (69.1%)	2 (3.4%), both were negative laparotomy	0:4 (3.1%)	4 (100%), all were NTL	N/A	0:0
Velmahos *et al.* 2001 (40) GSW abdomen	1856 (0/1856)	N/A	792 (42.7%)	140 (13.2%), NTL and Negative were not specified	80 (10.1%)	23 (28.8%), NTL vs Negative not specified	0:5 (6.3%) 4 intra-abdominal abscess and one ARDS	0:0
Navsaria *et al.* 2007 (26) SW abdomen	186 (186/0)	112 (60.2%)	N/A	8 (10.8%), 3 NTL and 5 negative laparotomies	12 (10.7%)	4 (33.3%), 2 NTL and 2 negative laparotomies	N/A	0
Clarke *et al*. 2010 (27) SW abdomen	340 (340/0)	148 (43.5%)	N/A	4 (2.1%)	30 (20.2%)	N/A	13 (43.3%)	0
Inaba *et al*. 2010 (44) GSW torso	787 (0/787)	N/A	636 (80.8%)	N/A	29 (4.6%)	2 (6.9%), 1 NTL and 1 negative laparotomy	N/A	N/A
Navsaria *et al*. 2011 (45) GSW pelvis	239 (0/239)	N/A	63 (26.4%)	4 (2.3%) all NTL	0	N/A	N/A	0
Zafar et al. 2012 (28) PAT abdomen	25737 (13030/12707)	5211 (40.0%)	3564 (28.0%)	2849 (36.4%)/1685 (18.4%)	791 (15.2%)/740 (20.8%)	278 (35.1%)/ 140(18.9%)	N/A	9(1.1%)/ 20(2.7%)
Navsaria *et al.* 2015 (35) GSW abdomen	1106 (0/1106)	N/A	272 (24.6%)	29 (3.5%), 17 NTL and 12 negative laparotomies	13 (4.8%)	3 (23.1%), 2 NTL and 1 negative laparotomy	0/7	1
Peponis *et al.* 2017 (46) GSW abdomen	922 (0/922)	N/A	215 (23.3%)	104 (14.7%) NTL and negative laparotomy are not specified	18 (8.4%)	1 (5.6%) NTL	9 (50%) Not directly related to delayed surgery	0
Al Rawahi *et al*. 2018 (36)	22847 (0/22847)	N/A	6777 (29.7%)	N/A	1019 (15.0%)	N/A	N/A	N/A
Sten Saar *et al.* 2021 (47)	119 (115/4)	55 (46.2%)	0	16 (30.8%)	3 (5.5%)	0	1 patient developed AKI not requiring dialysis	0
Sander *et al*. 2022 (8)	805 (303/502)	184 (60.7%)	147 (29.3%)	17/29	13 (7.1%)/ 11(7.5%)	(4/1)	N/A	N/A

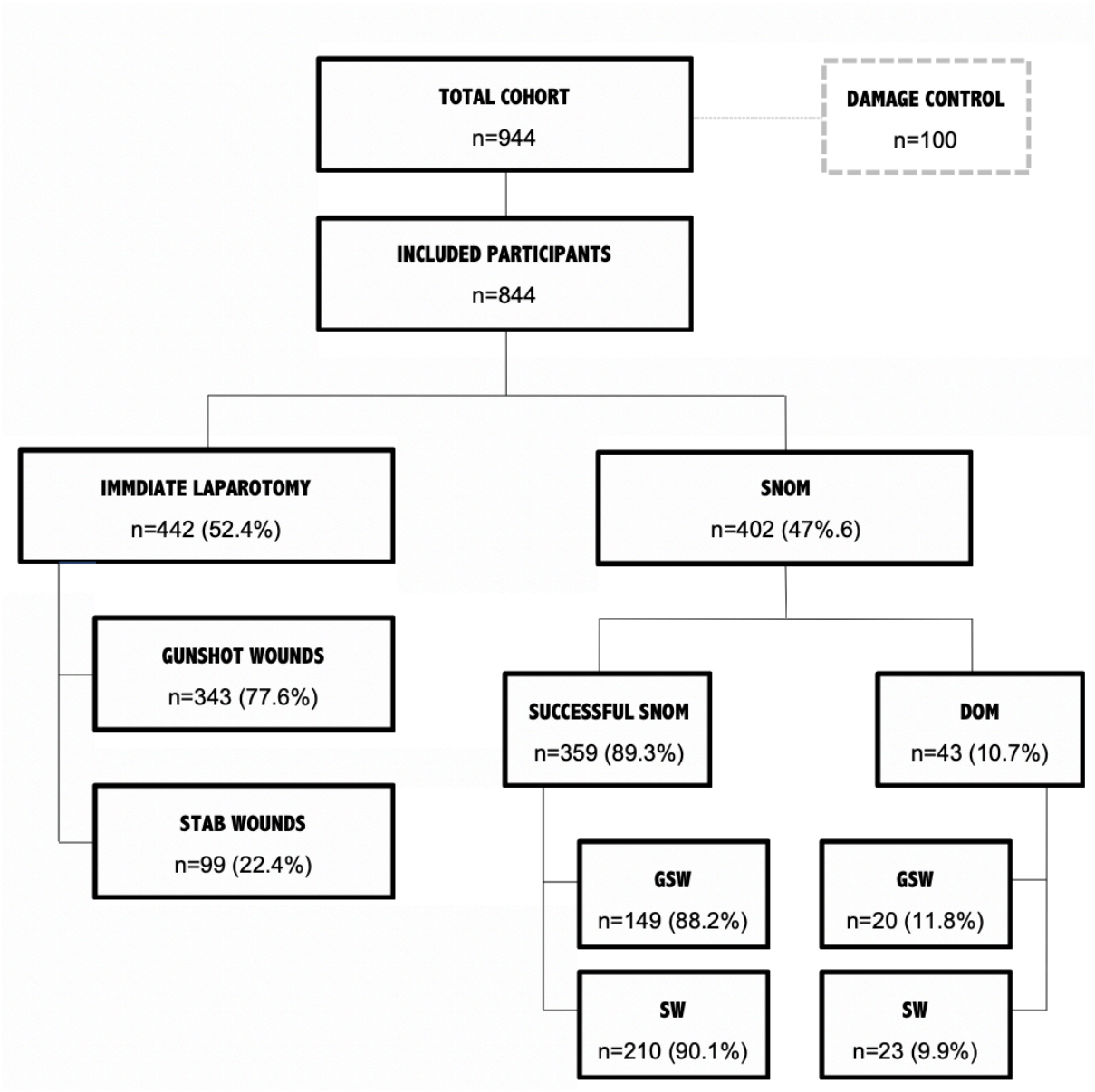

Figure 1. Schematic representation of participant selection in patients presenting with Penetrating abdominal trauma to Groote Schuur Hospital.

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APPENICES

Appendix 1: Study ethics approval

UNIVERSITY OF CAPE TOWN

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee

FHS016: Annual Progress Report / Renewal

HREC office use only (FWA00001637; IRB00001938)			
This serves as notification of annual approval, including any documentation described below.			
☐ Approved	Annual progress report	Approved until/next renewal date	30 01 23
☐ Not approved	See attached comments		
Signature Chairperson of the HREC/ Designee		Date Signed	7/2/22

Note: Please email this form and supporting documents (if applicable) in a combined pdf-file to hrec-enquiries@uct.ac.za.
Please clarify your plan for research-related activities during COVID-19 lockdown.
Please use the latest form found on our website:
http://www.health.uct.ac.za/fhs/research/humanethics/forms

Comments to PI from the HREC
Thank you for your Study Deviation HREC Chair Signature Date: 7/2/22

Principal Investigator to complete the following:

1. Protocol Information

Date (when submitting this form)	06-02-2022		
HREC REF Number	770/2017	Current Ethics Approval was granted until	31-03-2021
Protocol title	Outcomes following failure of selective non-operative management for penetrating abdominal trauma		
Protocol number (if applicable)	Project 2017/071		
Are there any sub-studies linked to this study?	☐ Yes	✓ No	
If yes, could you please provide the HREC Reference number for all sub-studies? Note: A separate FHS016 must be submitted for each sub-study.			
Principal Investigator	Pradeep Navsaria		
Department / Office Internal Mail Address	Trauma center/GSH Pradeep.navsaria@uct.ac.za		

HUMAN RESEARCH ETHICS COMMITTEE
- 7 FEB 2022
HEALTH SCIENCES FACULTY
UNIVERSITY OF CAPE TOWN

(Note: Please complete the Closure form (FHS010) if the study is completed within the approval period)