

Minimally Invasive Surgery in the Management of Blunt and Penetrating Abdominal Injuries: Two-decade Experience from a Brazilian Trauma Center

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ABSTRACT

Aim: Minimally invasive surgery (MIS) is becoming widely accepted as a useful diagnostic and therapeutic modality in acute trauma management. This study aims to describe the experience of a Brazilian trauma center with laparoscopic procedures for the management of abdominal trauma over a two-decade period.

Materials and methods: A retrospective analysis was conducted on all patients undergoing laparoscopy following blunt and penetrating abdominal trauma and admitted to a single trauma center from October 1997 to January 2019. Data on subjects' demographics, baseline presentations, diagnostic and therapeutic laparoscopic procedures performed, and outcomes were reported.

Results: Laparoscopic surgical exploration was performed on 225 patients presenting with abdominal trauma during the study period, including 28 (12.4%) patients sustaining blunt and 197 (87.6%) penetrating injuries, primarily stab wounds (68%; $n = 153$). The mean age was 30.2 ± 12.9 years (range 7–81) and the majority accounted for males (84%; $n = 189$). Negative laparoscopy and nontherapeutic procedures were recorded in 71 (31.5%) and 34 (15%) cases, respectively. After positive findings in diagnostic laparoscopic, 55 (24.4%) patients underwent exclusive minimally invasive repair and the remaining 65 cases (28.8%) required conversion to open surgery, thus avoiding 160 unnecessary laparotomies. No missed injuries were reported. The overall morbidity rate was 8.4%, with only 1.7% of complications being classified as severe, including two demises.

Conclusion: Diagnostic and therapeutic laparoscopy are an appropriate management in selected patients sustaining both blunt or penetrating abdominal trauma, with potentially improved outcomes compared with traditional approaches. Further research shall provide quality evidence for the establishment of standardized protocols to guide indications and limits of this technique in trauma practice.

Keywords: Blunt abdominal trauma, Laparoscopy, Penetrating abdominal injury, Trauma.

RESUMO

Objetivo: A evolução das técnicas minimamente invasivas vem possibilitando sua progressiva aplicação como ferramenta diagnóstica e terapêutica no cenário do trauma. O presente trabalho descreve a experiência de um centro de trauma brasileiro com procedimentos laparoscópicos no manejo do trauma abdominal contuso e penetrante em um período de duas décadas.

Materiais e métodos: Análise retrospectiva e revisão de prontuários de todos os pacientes submetidos a videolaparoscopia para manejo de trauma abdominal contuso ou penetrante admitidos em um único centro de referência, durante o período de outubro de 1997 a janeiro de 2019. Foram avaliados dados demográficos, mecanismo do trauma, indicações cirúrgicas, procedimentos diagnósticos e terapêuticos realizados, achados transoperatórios, taxa de conversão para cirurgia aberta, complicações pós-operatórias e mortalidade.

Resultados: Um total de 225 pacientes vítimas de trauma abdominal foi submetido a laparoscopia, sendo 197 (87.6%) por mecanismo penetrante, primariamente ferimentos por arma branca (77%; $n = 153$), e 28 (12.4%) por trauma contuso. A média de idade foi de 30.2 ± 12.9 anos (variação 7–81) com predomínio do sexo masculino (84%; $n = 189$). Laparoscopias negativas e não-terapêuticas foram registradas em 71 (31.5%) e 34 (15%) dos casos, respectivamente. Após um achado positivo na avaliação laparoscópica inicial, 55 (24.4%) pacientes foram submetidos ao reparo minimamente invasivo exclusivo e outros 65 casos (28.8%) requereram conversão para cirurgia aberta. A taxa de conversão para laparotomia foi de 26.9%, permitindo evitar um total de 163 cirurgias abertas. A taxa de complicações foi significativamente maior entre os pacientes submetidos à conversão para laparotomia. A morbidade geral foi de 8.4%, com apenas 1.7% das complicações sendo classificadas como severas, incluindo dois óbitos.

Conclusões: A adoção de técnicas minimamente invasivas em pacientes vítimas de trauma sofreu transformações e avanços ao longo do período estudado, acompanhando mudanças na prática clínico-cirúrgica. Os resultados aqui apresentados descrevem taxas de sucesso, conversão, intervenções terapêuticas e complicações equiparáveis ou preferíveis a séries de outros centros de trauma no mundo. A laparoscopia é uma alternativa segura e factível para diagnóstico e tratamento de lesões traumáticas abdominais, oferecendo potenciais vantagens sobre a cirurgia aberta desde que respeitadas as indicações adequadas e devido rigor técnico.

Palavras-chave: Laparoscopia, Trauma, Trauma abdominal penetrante, Trauma abdominal contuso.

Panamerican Journal of Trauma, Critical Care & Emergency Surgery (2020): 10.5005/jp-journals-10030-1268

INTRODUCTION

Minimally invasive surgery (MIS) is gradually being acknowledged as both a diagnostic and a therapeutic recourse in acute trauma management.^{1,2} Although persistent hemodynamic instability

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following blunt or penetrating abdominal injuries usually requires emergency laparotomy, the current evidence supports the indication of MIS in select groups of stable patients admitted to trauma centers with available technical expertise.³

The recent literature reported comparable safety and accuracy of laparoscopy to traditional open surgery concerning the detection and repair of certain abdominal organ injuries.⁴ Appropriate indications for MIS in trauma patients also offer several advantages, including fewer postoperative complications, better postoperative pain control, shortened hospitalization, faster functional recovery, less morbidity and mortality rates related to additional surgical trauma, and potential decreased financial burden.^{2,5-9}

This report describes the experience of a Brazilian trauma center with minimally invasive approach for blunt and penetrating abdominal trauma over a 21-year study period, thereby focusing on its applications, surgical management, effectiveness, and outcomes.

MATERIALS AND METHODS

The study was conducted at the Hospital de Pronto Socorro (HPS), the largest trauma center in the south of Brazil, located in Porto Alegre, state of Rio Grande do Sul. A retrospective observational analysis was performed on all patients undergoing laparoscopy following blunt and penetrating acute abdominal trauma at the institution.

Subjects were identified by query of the institutional surgical patient registry from October 1997 to January 2019. Data on demographics, mechanism of injury, indications for surgery, associated injuries, diagnostic and therapeutic procedures performed, operative findings, rates of conversion to open surgery, length of hospital stay, postoperative complications, and mortality were retrieved from individual patient records.

All patients were managed according to the advanced trauma life support guidelines upon admission. Subjects eligible for laparoscopy are required to be hemodynamically stable or respond to initial resuscitation (systolic blood pressure ≥ 90 mm Hg), observing institutional protocols. Exclusion criteria included unavailable medical records and laparoscopic surgeries performed to assess late complications in trauma patients.

The final decision to perform any minimally invasive procedure was based on the attending surgeon's discretion. Operations were performed by senior staff surgeons with advanced laparoscopic skills, with the participation of general and trauma surgery residents in training. Faculty remained relatively stable during the study period, and at least one of the attending surgeons had experience with minimally invasive techniques in each trauma shift.

Laparoscopic entry was achieved via the Veress needle or the open Hasson technique at the umbilicus with carbon dioxide insufflation to induce and maintain an intra-abdominal pressure limited to 15 mm Hg. Exploration was performed through insertion of a 30° scope 10 mm laparoscope and placement of additional 10 mm or 5 mm working ports where appropriate. It is noteworthy that the endoscopic equipment was not available on a 24-hour basis and throughout the year of 2010 due to technical issues. Special instruments, such as harmonic energy and laparoscopic stapling equipment, are not yet provided by the institution.

All surgical interventions were classified according to intraoperative findings as negative, when no injuries were identified; as nontherapeutic when an organ injury was identified but did not require specific treatment; as therapeutic, when surgical

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How to cite this article: Cunha CEB, Fonseca MK, de Souza Siebert Junior M, *et al.* Minimally Invasive Surgery in the Management of Blunt and Penetrating Abdominal Injuries: Two-decade Experience from a Brazilian Trauma Center. *Panam J Trauma Crit Care Emerg Surg* 2020;9(1):74–80.

Source of support: Nil

Conflict of interest: None

correction of organ injury was performed laparoscopically; and converted, if definitive repair required open surgical exploration. Evacuation of hemoperitoneum and mobilization of any intra-abdominal organs for diagnostic purposes were not considered therapeutic. Reported postoperative complications were defined according to the Clavien-Dindo classification system.

Descriptive statistics were performed for all variables. Parametric data are reported as means with standard deviation and nonparametric as median with interquartile range. The univariate analysis was performed by using the Student's *t* test to compare continuous variables and the Chi-square or Fisher's exact test was applied to compare categorical values where appropriate. The significance threshold was set at a *p* value of <0.05 . All statistical analysis was carried out using the IBM SPSS v24.0 software. Ethical approval for this study was obtained from the Municipal Health Secretariat Ethics and Research Committee of Porto Alegre (CEP-SMS) under the registration number 54367316.0.0000.5338.

RESULTS

Over the 21-year period from October 1997 to January 2019, a total of 232 patients with suspicious abdominal injuries following blunt or penetrating trauma underwent laparoscopic surgical exploration in Hospital de Pronto Socorro. Of these, seven cases were excluded from analysis due to either missing records ($n = 4$) or the laparoscopic procedure performed to manage intra-abdominal complications after initial laparotomy or selective nonoperative management ($n = 3$). Two hundred and twenty-five patients met study criteria and were included in the study. The rate of laparoscopic procedures decreased in spite of the reduction of overall trauma surgical explorations during this period, until a stable trend was reached within the last few years (Fig. 1).

Males accounted for 84% ($n = 189$) of the population. The mean age was 30.2 ± 12.9 years (range 7–81). One hundred and ninety-seven patients (87.6%) sustained penetrating trauma, primarily stab injuries (68%; $n = 153$) and the remaining 28 (12.4%) blunt injuries. Table 1 summarizes the baseline patient characteristics and outcomes.

The commonest reason to indicate a diagnostic laparoscopy was uncertainty of peritoneal violation ($n = 105$; 46.1%) and peritoneal breach in the absence of peritoneal signs ($n = 71$; 31.1%) for penetrating trauma. Wound entrance sites included 101 (51.2%) thoracoabdominal, 64 (32.5%) anterior abdominal wall, 25 (12.7%) flank, and 7 (3.5%) of the patients had injuries in more than one anatomic location. An abnormal physical examination (82%; $n = 23$) and hollow viscus injury suspected by computed tomography (CT) ($n = 2$; 7%) or focused assessment with sonography for trauma (FAST) findings ($n = 2$; 7%) were the main indications for surgery in blunt injuries. Table 2 lists the indications for laparoscopic surgical exploration according to the trauma mechanism.

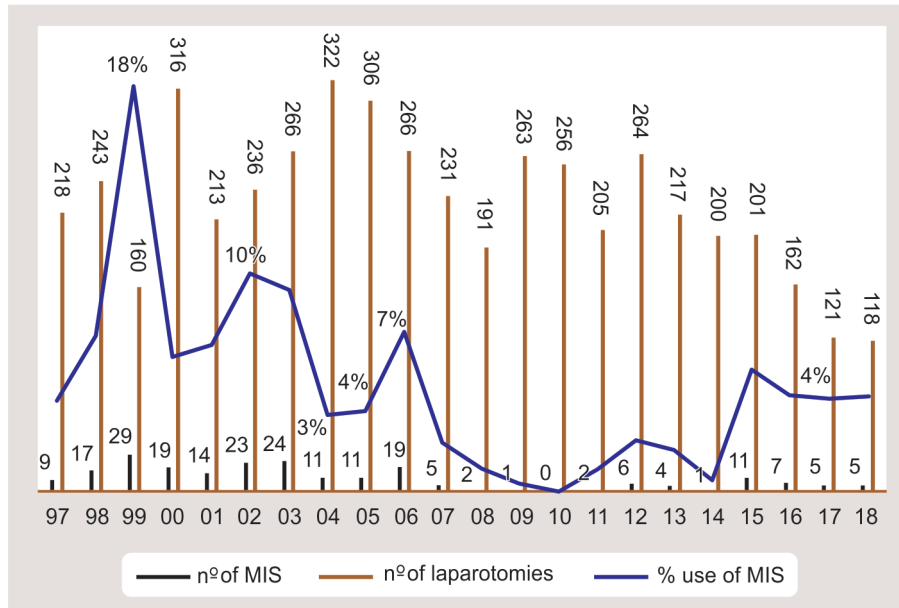


Fig. 1: Trends in annual laparoscopic procedures

Table 1: Baseline characteristics of patients undergoing laparoscopy

	n	(%)
Gender		
Male	189	84
Female	36	16
Age (years)	30.2 ± 12.9 (7–81)	
Mechanism of injury		
Blunt trauma	28	12.4
Penetrating trauma	197	87.6
Stab wounds	153	68
Gunshot wounds	44	19.6
Operative time (minutes)	81 (15–240)	
Length of hospital stay (days)	4.2	
Blunt trauma	6.4	
Penetrating trauma	3.8	
Stab wounds	3.1	
Gunshot wounds	6.4	

Common laparoscopic findings were liver, diaphragm, and small bowel injury in patients with penetrating trauma and small bowel, liver, and spleen lesions in patients with blunt injuries. Hemoperitoneum often resulted from injuries to the liver, spleen, mesentery, or abdominal wall. The incidence of lesions to the small bowel, spleen, and urinary bladder was significantly greater in patients sustaining blunt abdominal trauma. The laparoscopic findings stratified by injury type and repaired structures and organs are displayed in Table 3.

No significant injuries were identified in five patients sustaining blunt trauma and in other 66 with penetrating injuries upon an initial laparoscopic survey. Nontherapeutic laparoscopy was performed in 34 (15%) cases, 5 accounting for blunt and 29 for penetrating wounds. Intraoperative findings in this group included hemoperitoneum resulting from minor solid organ or abdominal wall lacerations, in which no further intervention was performed.

Table 2: Indications for surgery according to trauma mechanism

	n	(%)
Penetrating trauma (n = 197)		
Uncertain peritoneal violation	105	53.2
Peritoneal breach without peritonitis	71	36
Left thoracoabdominal injury	8	4
Evisceration	7	3.5
Peritoneal signs	3	1.5
Other	3	1.5
Blunt trauma (n = 28)		
Abnormal physical examination	23	82
Suspected hollow viscus injury on CT scan	2	7
Seat belt sign and FAST positive status	2	7
Trauma in pregnancy	1	3.5

After positive findings on diagnostic laparoscopy, 55 (24.4%) patients underwent exclusive laparoscopic repair, 6 due to blunt and 49 to penetrating injuries. The remaining 65 cases (28.8%) required conversion to open surgery to complete the procedure. The conversion rate to laparotomy was 26.9% (n = 53) for penetrating and 42.8% (n = 12) for blunt abdominal trauma patients, thus avoiding 160 unnecessary laparotomies. Procedures that required conversion were most commonly for intra-abdominal continuous bleeding, bowel injury, and multiple complex lesions. Classification of laparoscopic procedures performed is summarized in Table 4.

A broad variety of therapeutic procedures were successfully performed laparoscopically. The commonest organ repaired was the diaphragm, followed by the stomach, small bowel, colon, liver, and mesentery (Table 3). Otherwise, no missed injuries were reported.

Median operative time was 81 minutes (range 15–240) and the average length of stay in the hospital was 4.2 days, varying accordingly to injury type (7.1 days for blunt trauma, 3.1 for

Table 3: Laparoscopic findings stratified by injury type and injured organs repaired using minimally invasive surgery (MIS)

	<i>Penetrating (n)</i>	<i>(%)</i>	<i>Blunt (n)</i>	<i>(%)</i>	<i>Total (%)</i>	<i>p</i>
Hemoperitoneum	43	21.8	12	42.9	24.4	0.03*
Liver	48	24.4	4	14.3	23.1	0.33
Diaphragm	31	15.7	–	–	13.8	0.01
Small bowel	12	6.1	9	32.1	9.3	0.001*
Stomach	21	10.7	–	–	9.3	0.08
Spleen	10	5.1	5	17.9	6.7	0.02*
Colon	10	5.1	3	10.7	5.8	0.21
Mesentery	9	4.6	3	10.7	5.3	0.17
Abdominal wall	2	1	1	3.6	1.3	0.33
Greater omentum	3	1.5	1	3.6	1.8	0.41
Pancreas	3	1.5	–	–	1.3	1.0
Mesocolon	3	1.5	–	–	1.3	1.0
Kidney						
Left	2	1	1	3.6	1.3	0.33
Right	1	0.5	0	–	0.4	1.0
Gallbladder	2	1	–	–	0.9	1.0
Rectum	1	0.5	1	3.6	0.9	0.23
Bladder	–	–	2	7.1	0.9	0.01*
Duodenum	1	0.5	–	–	0.4	1.0
Esophagus	1	0.5	–	–	0.4	1.0
Ureter	1	0.5	–	–	0.4	1.0
Inferior vena cava	1	0.5	–	–	0.4	1.0

*Repaired structures and organs using MIS**No. of cases*

Diaphragm—repair	22
Stomach—primary closure	7
Small bowel—primary closure	5
Colon—primary closure	9
Liver—hemostasis	8
Mesentery/omentum—hemostasis	5
Bladder—primary closure	1
Rectum—primary closure	1
Spleen—hemostasis	2

*Significance level: $p < 0.05$ **Table 4:** Classification of laparoscopic procedures stratified by injury type

<i>Laparoscopic procedures</i>	<i>Blunt trauma</i>		<i>Penetrating trauma</i>		<i>Total</i>		<i>p</i>
	<i>n</i>	<i>(%)</i>	<i>n</i>	<i>(%)</i>	<i>n</i>	<i>(%)</i>	
Negative	5	17.8	66	33.5	71	31.5	0.12
Nontherapeutic	5	17.8	29	14.7	34	15	0.58
Therapeutic	6	21.4	49	24.8	55	24.4	0.82
Converted	12	42.8	53	26.9	65	28.8	0.12
Total	28	100	197	100	225	100	
Conversion rate (%)		42.8		26.9		28.8	
Laparotomies avoided		16		144		160	

penetrating stab lesions, and 6.4 for penetrating gunshot wounds), as shown in Table 1.

Postoperative morbidity is reported according to the Clavien-Dindo classification as shown in Table 5. Minor complications (Clavien-Dindo I and II) in patients subjected to laparoscopic surgical exploration (negative, nontherapeutic, and therapeutic) included six cases of pneumonia and one case of urinary tract

infection. In those patients requiring conversion to open surgery, two cases of ileus, three of pneumonia, two wound infections, and one intraabdominal abscess were reported. No major clinical events (Clavien-Dindo III and IV) were disclosed in the laparoscopic group. Conversely, one case of pancreatic fistulae and one iatrogenic injury to the ureter occurred in patients submitted to conversion.

Table 5: Significant complications and overall morbidity

Complications	Laparoscopy (n = 160)		Conversion to laparotomy (n = 65)		Total (n = 225)		p
	n	(%)	n	(%)	n	(%)	
Clavien-Dindo I-II	7	4.4	8	12.3	15	6.6	0.03*
Clavien-Dindo III-IV	–	–	2	3.1	2	0.8	0.02*
Clavien-Dindo V	1	0.6	1	1.5	2	0.8	0.51
Overall morbidity	8	5	11	17	19	8.4	0.003*

*Significance level: $p < 0.05$

Two deaths (Clavien-Dindo V) were recorded, both involving male patients sustaining stab wounds to the abdomen. The first occurred due to a zone III retroperitoneal hematoma that was not explored laparoscopically. The patient developed hemorrhagic shock postoperatively and was subjected to emergency laparotomy, in which an injury in the common iliac vein was identified and repaired. The second patient was submitted to CT scan prior to surgery, in which a renal injury was identified and not explored during surgery. The manipulation of the left colon probably released the retroperitoneal hematoma, thus leading to hemorrhagic shock and conversion to open surgery. Despite adequate treatment, both patients died of clinical complications following damage control surgery. These mortalities, however, could not be attributed to laparoscopic examination itself.

The overall morbidity rate was 8.4% with only 1.7% of complications being classified as severe. The incidence of mild, severe, and overall complications was significantly lower among patients submitted exclusively by laparoscopy, as disclosed in Table 5.

DISCUSSION

Advancements in surgical technology and the improvement of laparoscopic skills over the past decades have allowed the widespread implementation of MIS as the standard of care for an ever-expanding number of abdominal operations,^{5,10,11} including advanced elective procedures as well as many emergencies.^{8,12} A wide body of literature has consistently demonstrated less invasive approaches to be safe and equally efficient to open surgery in selected cases, besides providing clinically beneficial advantages regarding surgical morbidity and patient recovery.^{3,13,14} These benefits are particularly appealing in the trauma setting, in which exploratory laparotomy has been historically the traditional mainstay of treatment for abdominal injuries.^{11,13} Indeed, several studies have reported the effect of MIS on reducing negative and nontherapeutic laparotomy rates and its associated complications in as much as 60%.^{15–17}

The efficacy of laparoscopy as a diagnostic and a therapeutic tool in both blunt and penetrating abdominal trauma has been demonstrated in several reports. Diagnostic laparoscopic is a well-established technique for the assessment of intraabdominal injuries, as current imaging modalities may not ascertain specific diaphragmatic, mesenteric, and hollow viscus injuries.¹⁸ Current indications include the investigation of isolated free-fluid accumulation in the abdominal cavity identified on CT scan, assessment of diaphragmatic injuries due to thoracoabdominal trauma, diagnosis of peritoneal violation following stab wounds, and suspected but unproven hollow viscus injury in hemodynamically stable patients.^{2,5,18,19} Further applications comprise many therapeutic possibilities in patients requiring intervention, such as

the laparoscopic repair of gastrointestinal, bladder, and diaphragm perforations and the hemostasis of solid organ, mesentery, or abdominal wall lacerations, as reported in previous retrospective reviews and case series.^{18,20,21}

Despite its significant potential advantages, a number of concerns have limited the application of MIS in trauma patients. Contraindications for laparoscopy are an issue for potential injured candidates, as hemodynamic instability due to severe hemorrhagic shock and brain injury is common presentations of trauma patients.^{2,6} The high rates of missed visceral injury and increased operative time reported in early studies are still major apprehensions among surgeons.^{2,3,18,22} The reproducibility of more contemporary study outcomes is also subject to considerable skepticism, as it depends on staff expertise and training, availability of equipment, and facility resources,^{5,9,23,24} which may vary between institutions.

Technical issues regarding adequate exposure of retroperitoneal structures and large hemorrhagic infiltrations,²³ and the repair of multiple complex injuries,²⁵ undeniably require advanced laparoscopic skills. The presence of significant bowel distension and the third-trimester gravid uterus may also pose limitations to abdominal cavity inventory.²³ The development of a standard examination routine of the peritoneal cavity, as devised by Kawahara et al.,²¹ as well as growing surgeon experience^{8,19,26} have been shown to increase laparoscopic accuracy in trauma patients, with a large number of recent studies reporting no missed injuries.^{19,22,24,27} Notwithstanding the promising results of laparoscopic surgery in the trauma setting, evidence-based recommendations are limited to few prospective studies and practice guidelines are not yet available.

Up to the best of our knowledge, this is the first report to describe the evolution and changing trends of MIS in trauma patients from our region. Laparoscopy has been adopted in other elective and emergency nontrauma-related procedures since its establishment in our institution in 1997. This report shows a significant decrease in the use of MIS in trauma patients, shifting from an initial interest in a novel technique to a better definition of its limits and indications. The improvement of imaging techniques²⁸ and the increasing role of selective nonoperative management of both blunt²⁹ and penetrating^{30,31} abdominal trauma may have warranted a more precise selection of patients and ultimately declined the use of laparoscopy over the years.

Minimally invasive techniques have obviated laparotomy in as many as 160 patients (71%) in our institution, which is at least comparable to most recent reports, as shown by Cirocchi et al.²⁸ This systematic review of thirty-five studies disclosed that MIS averted 73.8% nontherapeutic laparotomies in both blunt and penetrating trauma. The success rate of our therapeutic laparoscopies was 24.4% (55/225), also similar to the series included in the systematic review (23.4%).

Conversion to open surgery was required in 65 of our cases (28.8%), mostly due to blunt (42.8%) than to penetrating trauma (26.9%), with no statistical significance. The conversion rate varies among studies depending on selection criteria and attending surgeon's expertise. Matsevych et al.¹⁹ also observed differences in rates of conversion according to the mechanism of injury, being 22.9% for blunt and 11.7% for penetrating trauma. The systematic review performed by Cirocchi et al.²⁸ disclosed a conversion rate of 26.2% for both blunt and penetrating trauma. Similar results were reported by a large national trauma databank reviewed by Zafar et al.⁹ (20.2%) and more recent case series conducted by Lim et al.²² (18%).

Many of these laparoscopic diagnostic and therapeutic procedures were performed by general surgery and trauma residents under the supervision of a surgeon consultant, which states the safety and feasibility of MIS for trauma patients in a training setting, as has been shown in other series.²⁶

This general overview traces the implementation of laparoscopic techniques in the management of abdominal trauma and its improvements over time in our institution, which have evolved according to the continuous changes in the surgical practice. The main limitations of this study are its retrospective observational nature, the lack of a well-defined comparative open surgery and/or nonoperative management group, the impossibility to assess long-term follow-up, and the absence of an institutional protocol, which may induce selection bias on study outcomes. Further prospective randomized and controlled studies are expected to validate proper indications and issue the standardization of laparoscopy in acute trauma management.

CONCLUSION

Diagnostic and therapeutic laparoscopy are an appropriate management for patients sustaining both blunt or penetrating abdominal trauma, with potentially improved outcomes compared with traditional approaches in selected cases. Further research shall provide quality evidence for the establishment of standardized protocols to guide indications and limits of the technique in surgical practice.

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