ORIGINAL ARTICLE

Intra-abdominal Infection in Patients With Abdominal Trauma

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Hypothesis: Identifying patients with risk factors associated with the development of intra-abdominal infections makes possible early interventions to minimize morbidity and mortality. We sought to determine the incidence of intra-abdominal infection (organ/space surgical site infection) in patients undergoing operation because of abdominal trauma, to identify the risk factors associated with the development of this complication, and to estimate the respective magnitudes of the risk factors.

Design: We performed a prospective cohort study in patients older than 12 years who were treated surgically for penetrating or blunt abdominal trauma, with or without other associated lesions.

Setting: Hospital Universitario San Vicente de Paul in Medellín, Colombia (HUSVP), a level I trauma center for referral and the general community.

Patients: From November 1, 2000, through August 31, 2002, 916 patients with abdominal trauma were admitted to the HUSVP trauma unit. Of these, we excluded 2 who underwent operation at different institutions; 97 (10.6%) who died within 48 hours after admission; and 55 (6.0%) in whom complete follow-up (until the 30th postoperative day) was not feasible. The final study sample consisted of 762 patients.

Main Outcome Measure: We performed univariate analysis to explore in an isolated way the behavior of the dependent and independent variables. Bivariate analysis was carried out with each of the independent variables and the main outcome to establish the association between individual risk factors and intra-abdominal infection. Finally, a logistic regression model was developed using the SPSS 10.0 program and the forward method.

Results: Intra-abdominal infection developed in 81 patients (10.6%). Variables independently associated with this complication were an Abdominal Trauma Index greater than 24, abdominal contamination, and admission to the intensive care unit.

Conclusions: The development of intra-abdominal infection in patients undergoing operation because of abdominal trauma is a complex phenomenon resulting from the multiple risk factors during the preoperative, intraoperative, and postoperative periods. Multivariate logistic regression analysis allowed us to identify an Abdominal Trauma Index greater than 24, contamination of the abdominal cavity, and admission to the intensive care unit as independent risk factors for the development of organ/space surgical site infection.

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INFECTION IS RESPONSIBLE FOR MOST deaths in trauma patients who survive longer than 48 hours after trauma.[1,2] Intra-abdominal infection (organ/space surgical site infection) in patients with abdominal trauma constitutes one of the most frequent infectious problems and poses a major challenge to trauma surgeons. Its incidence fluctuates from 2% to 9%,[1-3] and it is associated with many different complications, including acute respiratory distress syndrome, multiple organ failure (MOF), gastrointestinal tract fistulae, abdominal wall defects, malnutrition, and psychological problems.[4] Frequently, these patients must be admitted to the intensive care unit (ICU), the length of their hospital stay extends, and the cost of their medical care increases. Mortality rate secondary to intra-abdominal infection is high, from 1% to 7%,[5] but it is higher than 50% if diagnosis is delayed after development of MOF.[6]

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The development of infection in trauma patients depends on the interaction of multiple factors such as previous health conditions, lesions caused by the trauma and their complications, and, finally, the treatment modality. Therefore, it is advisable to maintain a high degree of suspicion when clinical evo lution does not proceed as expected, to identify those patients at greater risk of intra-abdominal infection and to attempt prevention.

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Table 1. Statistical Indicators of Quantitative Variables in Patients Undergoing Operation for Abdominal Trauma, HUSVP, 2000-2002

Variables	No. of Patients	Mean	Median	SD
Age, y	749	27.92	25.00	10.57
Time elapsed from trauma to surgery, h	755	7.52	3.00	28.00
RTS	757	7.49	7.84	0.84
ISS	762	15.42	16.00	9.39
Transfused blood (autologous and heterologous), U	208	3.02	2.00	2.25
ATI	762	15.47	13.00	11.75
Duration of the operation, min	759	120.30	110.00	65.58
Duration of packing, h	42	46.45	48.00	16.96
Hospital stay, d	761	9.49	5.00	13.06
ICU stay, h	110	207.50	136.50	215.17

Abbreviations: ATI, Abdominal Trauma Index; HUSVP, Hospital Universitario San Vicente de Paúl, Medellín, Colombia; ICU, intensive care unit; ISS, Injury Severity Score; RTS, Revised Trauma Score.

Table 2. Relationship Between Intra-abdominal Infection and Some Preoperative Variables, HUSVP, 2000-2002

	Intra-abdominal Infection, No. (%)*				
Variables	Yes	No	Total No. of Infections	RR (95% CI)	*P* Value
Sex					
Female	6 (9.0)	61 (91.0)	**67**	0.813 (0.31-2.04)	.64
Male	75 (10.8)	620 (89.2)	**695**		
Total	**81** (10.6)	**681** (89.4)	**762**		
Age, y					
<55	75 (10.2)	657 (89.8)	**732**	1.88 (0.42-7.18)	.32
≥55	3 (17.6)	14 (82.3)	**17**		
Total	**78** (10.4)	**671** (89.6)	**749**		
History of laparotomy					
No	76 (10.5)	647 (89.5)	**723**	1.22 (0.52-2.84)	.65
Yes	5 (12.8)	34 (87.2)	**39**		
Total	**81** (10.6)	**681** (89.4)	**762**		
Etiologic agent					
Stab wound	13 (5.4)	226 (94.6)	**239**		
Firearm	56 (12.7)	386 (87.3)	**442**	2.33 (1.3-4.17)	.003
Blunt trauma	12 (15.2)	67 (84.8)	**79**	2.79 (1.33-5.87)	.005
Total	**81** (10.7)	**679** (89.3)	**760**		
Time elapsed between trauma and surgery, h					
<6	61 (11.6)	467 (88.4)	**528**	0.72 (0.44-1.18)	.19
≥6	19 (8.4)	208 (91.6)	**227**		
Total	**80** (10.6)	**675** (89.4)	**755**		
Use of antibiotics					
Preoperative	48 (8.8)	498 (91.2)	**546**		
Intraoperative and postoperative	16 (12.3)	114 (87.7)	**130**	1.4 (0.82-2.38)	.22
None	17 (19.8)	69 (80.2)	**86**	2.25 (1.36-3.72)	.001
Total	**81** (10.6)	**681** (89.4)	**762**		

Abbreviations: CI, confidence interval; HUSVP, Hospital Universitario San Vicente de Paul, Medellín, Colombia; RR, relative risk.
*Percentages have been rounded and may not total 100.

We sought to determine the incidence of intra-abdominal infection in patients undergoing operation because of abdominal trauma, to identify the risk factors associated with the development of this complication, and to estimate their respective magnitudes.

METHODS

We performed a prospective cohort study in patients older than 12 years, surgically treated for penetrating or blunt abdominal trauma, with or without other associated lesions, who were admitted to the trauma unit of Hospital Universitario San Vicente de Paul, Medellín, Colombia (HUSVP). This is a level I urban trauma center located in a city of 2 million inhabitants.

The main outcome was intra-abdominal infection; secondary outcomes were mortality, nosocomial infections other than intra-abdominal infection, and microorganisms isolated. Criteria developed at the Centers for Disease Control and Prevention, Atlanta, Ga, by the National Nosocomial Infections Surveillance were used for diagnosis.[6,7] The following risk factors were evaluated during the preoperative, intraoperative, and early postoperative periods: age, sex, mechanism of the lesion, time elapsed from trauma to surgical intervention, Revised Trauma

Score (RTS), Injury Severity Score (ISS), Abdominal Trauma Index (ATI), intraoperative hypotension, preoperative transfusion, number of total units of transfused blood, surgical time, surgical procedures other than laparotomy, number of contaminated abdominal quadrants, need for ostomy or splenectomy, use of drains and packing, open abdomen, damage-control surgery, reoperations, and admission to the ICU.

Death was regarded as due to intra-abdominal infection when it occurred in the 2 weeks after the onset of the complication, and if signs of infection were present at the moment of its occurrence.

The study protocol was approved by the Ethics Committees of the University of Antioquia, Medellín, and the HUSVP. The size of the sample was calculated according to the method of Breslow and Day,[8] with a 95% confidence level (CI) ($\alpha = .05$) and an 80% power to detect a relative risk (RR) of 2.5. The estimated total was 809, including an additional 10% for possible follow-up losses.

We performed univariate analysis to explore in an isolated way the behavior of dependent and independent variables, quality of the data, and presence of extreme values. We performed bivariate analysis with each of the independent variables and the main outcome to establish the association between individual risk factors and intra-abdominal infection. Finally, a logistic regression model was developed using the SPSS 10.0 program (SPSS Inc, Chicago, Ill) and the forward method.

RESULTS

From November 1, 2000, through August 31, 2002, 916 patients with abdominal trauma were admitted to the trauma unit of the HUSVP. Of these, we excluded 2 who underwent operation at different institutions; 97 (10.6%) who died within 48 hours after admission; and 55 (6.0%) in whom complete follow-up (until the 30th postoperative day) was not feasible. Of the remaining 762 patients, intra-abdominal infection developed in 81 (10.6%).

DEMOGRAPHIC DATA

Of the 762 patients, 695 (91.2%) were male and 67 (8.8%) were female. Their average age was 27.9 years (SD, 10.57 years; range, 12-72 years), and 15 patients were younger than 16 years. Six hundred eighty-one lesions (89.4%) were penetrating and 79 (10.4%) were blunt. This information was not available in the remaining 2 cases. Of the 681 penetrating lesions, 239 (35.1%) were produced by stab wounds; 435 (63.9%), by firearms of single or multiple charge; and 7 (1.0%), by explosive artifacts.

In **Table 1**, the studied quantitative variables are summarized, including age of the patients, scores of the trauma indexes (RTS, ISS, and ATI), time elapsed from trauma to surgery, length of the surgical intervention and packing, duration of the hospital and ICU stays, and amount of total blood transfused (heterologous and autologous).

INCIDENCE AND TYPES OF INFECTIOUS COMPLICATIONS

Intra-abdominal infection developed in 81 patients (10.6%), with distribution as follows: peritonitis in 42 cases (51.9%); intra-abdominal abscesses in 34 (42.0%); and leak of pus through drains or traumatic orifices in 5 (6.2%). Cultures for aerobes were performed on 63 (77.8%) of the 81 patients, and 90 isolates were obtained. The most frequent isolates included *Escherichia coli* (n=39 [43.3%]), *Staphylococcus aureus* (n=17 [18.9%]), *Klebsiella pneumoniae* (n=13 [14.4%]), and *Enterococcus faecalis* (n=5 [5.6%]). Cultures for anaerobes were not performed. Average time from initial surgery to the diagnosis of intra-abdominal infection was 8.39 days (range, 1-40 days).

One hundred nine patients (14.3%) had nosocomial infections other than intra-abdominal infection, including superficial and deep incisional surgical site infection in 52 cases (47.7%), respiratory tract infection in 19 (17.4%), urinary tract infection in 12 (11.0%), catheter-associated sepsis in 11 (10.1%), empyema in 8 (7.3%), central nervous system infection in 2 (1.8%), and other infections in 5 (4.6%).

Patients with intra-abdominal infection and other nosocomial infections were included only in the former group if the isolates from both sites were similar.

MORTALITY

Twenty-nine (3.8%) of the 762 patients died more than 48 hours after their admission. Of these deaths, 11 (37.9%) were attributable to abdominal infection; 3 (10.3%), to infections in other sites; 13 (44.8%), to MOF; 1 (3.4%), to bronchoaspiration; and 1 (3.4%), to homicide.

BIVARIATE ANALYSIS

The frequency of intra-abdominal infection and the RR with its 95% CI and the corresponding *P* values are presented in **Table 2** (for preoperative variables); **Table 3** (for trauma severity indexes [RTS, ISS, and ATI]); **Table 4** (for intraoperative variables, ie, intraoperative hypotension [systolic pressure <90 mm Hg for ≥1 hour], abdominal cavity contamination, total blood transfusion, duration of the surgery, use of drains, and splenectomy, ostomy, and associated operations); and **Table 5** (for postoperative variables, ie, open abdomen, packing, damage-control surgery, and admission to the ICU).

The decision to administer antibiotics and when was made by the attending surgeon. The most frequently used antibiotic was ampicillin/sulbactam.

Nontherapeutic laparotomies were performed in 54 patients; infection developed in only 1 (1.9%) of them.

The decision to place drains was made intraoperatively by the surgeon; they were usually used in patients with urinary tract or pancreatic lesions and in those with serious injuries of solid organs.

Seventy-five planned reoperations were performed in 58 patients. Of these, 18 (24.0%) were because of open abdomen; 13 (17.3%), damage-control surgery; and 44 (58.7%), packing.

The following were risk factors for development of intra-abdominal infection during the preoperative period: gunshot wounds, blunt trauma, and the lack of use of prophylactic antibiotics. All of the evaluated trauma severity indexes were associated with infection, and the following scores behaved as risk factors: RTS of less than

Table 3. Relationship Between Intra-abdominal Infection and Trauma Severity Indexes, HUSVP, 2000-2002

Variables	Intra-abdominal Infection, No. (%)* Yes	No	Total	RR (95% CI)	*P* Value
ISS					
≤20	54 (9.0)	546 (91.0)	**600**	1.85 (-2.84 to 1.21)	.0049
>20	27 (16.7)	135 (83.3)	**162**		
Total	**81** (10.6)	**681** (89.4)	**762**		
RTS					
>7.8	47 (8.2)	524 (91.8)	**571**	2.14 (1.42 to 3.24)	<.001
≤7.8	33 (17.6)	154 (82.4)	**187**		
Total	**80** (10.6)	**678** (89.4)	**758**		
ATI					
≤24	38 (6.2)	576 (93.8)	**614**	4.69 (3.15 to 6.99)	<.001
>24	43 (29.0)	105 (70.9)	**148**		
Total	**81** (10.6)	**681** (89.4)	**762**		

Abbreviations: ATI, Abdominal Trauma Index; CI, confidence interval; HUSVP, Hospital Universitario San Vicente de Paul, Medellín, Colombia; ISS, Injury Severity Score; RR, relative risk; RTS, Revised Trauma Score.
*Percentages have been rounded and may not total 100.

Table 4. Relationship Between Intra-abdominal Infection and Some Intraoperative Variables, HUSVP, 2000-2002

Variables	Intra-abdominal Infection, No. (%)* Yes	No	Total No. of Infections	RR (95% CI)	*P* Value
Intraoperative systolic hypotension†					
No	44 (7.2)	563 (92.8)	**607**	3.29 (2.21-4.91)	<.001
Yes	37 (23.9)	118 (76.1)	**155**		
Total	**81** (10.6)	**681** (89.4)	**762**		
Abdominal cavity contamination					
None	18 (4.9)	348 (95.1)	**366**		
1 Quadrant	22 (10.5)	188 (89.5)	**210**	2.13 (1.17-3.88)	.001
2 Quadrants	23 (20.0)	92 (80.0)	**115**	4.07 (2.28-7.26)	<.001
3 Quadrants	6 (20.7)	23 (79.3)	**29**	4.21 (1.81-9.77)	.001
4 Quadrants	10 (35.7)	18 (64.3)	**28**	7.26 (3.71-14.2)	<.001
Total	**79** (10.6)	**669** (89.4)	**748**		
Amount of transfused blood, U					
None	37 (6.7)	514 (93.3)	**551**		
1-2	15 (13.4)	97 (86.6)	**112**	1.99 (1.13-3.51)	.01
3-4	18 (27.3)	48 (72.7)	**66**	4.47 (2.72-7.34)	<.001
5-6	11 (36.7)	19 (63.3)	**30**	5.46 (3.11-9.60)	<.001
Total	**81** (10.7)	**678** (89.3)	**759**		
Duration of operation, h					
≤2	34 (6.6)	479 (93.4)	**513**	3.1 (1.93-4.99)	<.001
>2	47 (19.1)	199 (80.9)	**246**		
Total	**81** (10.7)	**678** (89.3)	**759**		
Drains					
No	53 (8.8)	549 (91.2)	**602**	1.99 (1.3-3.04)	.001
Yes	28 (17.5)	132 (82.5)	**160**		
Total	**81** (10.6)	**681** (89.4)	**762**		
Splenectomy					
No	68 (9.6)	642 (90.4)	**710**	2.61 (1.55-4.40)	<.001
Yes	13 (25.0)	39 (75.0)	**52**		
Total	**81** (10.6)	**681** (89.4)	**762**		
Ostomies					
No	65 (9.2)	641 (90.8)	**706**	3.1 (1.93-4.99)	<.001
Yes	16 (28.6)	40 (71.4)	**56**		
Total	**81** (10.6)	**681** (89.4)	**762**		
Associated operations‡					
No	48 (10.3)	418 (89.7)	**466**	1.08 (0.71-1.64)	.71
Yes	33 (11.2)	263 (88.9)	**296**		
Total	**81** (10.6)	**681** (89.4)	**762**		

Abbreviations: CI, confidence interval; HUSVP, Hospital Universitario San Vicente de Paul, Medellín, Colombia; RR, relative risk.
*Percentages have been rounded and may not total 100.
†Indicates systolic pressure <90 mm Hg during ≥1 hour.
‡Indicates site different from the abdomen.

Table 5. Relationship Between Intra-abdominal Infection and Some Postoperative Variables, HUSVP, 2000-2002

Variables	Intra-abdominal Infection, No. (%)* Yes	No	Total	RR (95% CI)	*P* Value
Open abdomen					
No	70 (9.4)	674 (90.6)	**744**	6.5 (4.22-9.99)	<.001
Yes	11 (61.1)	7 (38.9)	**18**		
Total	**81** (10.6)	**681** (89.4)	**762**		
Damage control					
No	76 (10.1)	673 (89.9)	**749**	3.79 (1.85-7.79)	.001
Yes	5 (38.5)	8 (61.5)	**13**		
Total	**81** (10.6)	**681** (89.4)	**762**		
Packing					
No	61 (8.5)	657 (91.5)	**718**	5.35 (3.58-8.01)	<.001
Yes	20 (45.5)	24 (54.5)	**44**		
Total	**81** (10.6)	**681** (89.4)	**762**		
Admission to ICU†					
No	35 (5.4)	615 (94.6)	**650**	7.63 (5.16-11.28)	<.001
Yes	46 (41.1)	66 (58.9)	**112**		
Total	**81** (10.6)	**681** (89.4)	**762**		

Abbreviations: CI, confidence interval; HUSVP, Hospital Universitario San Vicente de Paúl, Medellín, Colombia; ICU, intensive care unit; RR, relative risk.
*Percentages have been rounded and may not total 100.
†Indicates cause different from that of the intra-abdominal infection.

Table 6. Logistic Regression

Variables	β Coefficient	*P* Value	RR (95% CI)
ATI	0.97	.001	2.63 (1.48-4.67)
Admission to ICU	2.13	<.001	8.38 (4.76-14.73)
Abdominal cavity contamination	0.96	.002	2.62 (1.44-4.78)
K	–3.67	<.001	0.03

Abbreviations: ATI, Abdominal Trauma Index; CI, confidence interval; ICU, intensive care unit; *K*, statistical constant; RR, relative risk.

7.8, ATI greater than 24, and ISS greater than 20. Intraoperative risk factors were systolic hypotension, abdominal cavity contamination, transfusion, operations longer than 2 hours, drains, ostomy, and splenectomy. In regard to the postoperative period, variables associated with infection were packing, damage-control surgery, open abdomen, and admission to the ICU.

MULTIVARIATE ANALYSIS

We used the SPSS program for multivariate analysis; the technique for making logistic regression was the forward method. Quantitative variables were categorized, and dummy variables were generated for those with 3 or more categories. Independent variables that, according to the Hosmer-Lemeshow criterion, had a *P* value of less than .25 in bivariate analysis, were selected as candidates for the logistic regression model. The last step model was selected, taking into account the Hosmer-Lemeshow goodness-of-fit test ($P>.05$).

The following variables were independently associated with intra-abdominal infection: an ATI score greater than 24, abdominal contamination, and admission to the ICU (**Table 6**). This model adjusts well (Hosmer-Lemeshow goodness-of-fit test, $P=.70$) and predicts 90.5% of the events, but it cannot be used as a predictor because it explains only 30% of the variability of the dependent variable (outcome) (R^2 Nagelkerke, 0.30) and because of the scattered distribution of residuals.

COMMENT

This work was designed to prospectively determine the incidence of intra-abdominal infection in patients undergoing operation for abdominal trauma and was performed at a level I urban trauma center in Medellín.

In comparison with the results of other reports,[3,9-11] the 10.6% incidence of intra-abdominal infection found in our series was similar, but that of other nosocomial infections (14.3%) was lower probably because patients with both situations and identical bacterial isolates were included only in the intra-abdominal infection group. Our microbiological findings in cases of abdominal sepsis were similar to those of other studies that included a trauma patient population.[9]

Ninety-seven (10.6%) of the initial 916 patients died during the first 48 hours after trauma (early mortality), and 29 (3.8%) of our final study sample died after that period (late mortality). In the latter group, 11 patients (37.9%) died as a consequence of abdominal infection.

In the presence of severe trauma (ISS, >20) and the same etiologic agent, women have significantly lower risk than men of development of sepsis and MOF. In comparison with women, men exhibit significantly higher levels of interleukin 6 and procalcitonin and, consequently, a more intensive inflammatory state develops.[12] Intra-abdominal infection was documented in only a small number of women, and no significant difference was found in the occurrence of intra-abdominal infection according to sex.

When compared with younger patients, trauma patients older than 55 years have a 20% to 30% decrease in their probability of survival. This may be explained on the basis of a lesser physiological reserve, a decrease in the immune response, and other age-related changes.[13] In this study, intra-abdominal infection was found only in a small group of patients older than 55 years, and it was not possible to demonstrate differences in the occurrence of intra-abdominal infection according to age.

Relevant pathologic facts were found in the clinical history of 72 patients (9.4%), the most frequent being previous laparotomy in 39 cases. No association could be established between these factors and the development of organ/space surgical site infection.

A higher risk of intra-abdominal infection was found in patients with penetrating trauma due to firearm wounds or with blunt trauma, compared with those wounded by stabbing. Although any kind of weapon may cause wounds of equivalent severity, in terms of anatomic lesions and physiological alterations, stabbing weapons generally produce localized lesions of predictable trajectory. Consequently, in their surgical approach, it is easier to repair lesions, control bleeding, and limit the amount of contamination. All of these circumstances may help to decrease the probability of infection.

There was no difference in the risk of infection between patients who underwent operation less than vs greater than or equal to 6 hours after trauma, perhaps because more seriously wounded individuals receive immediate attention.

The Eastern Association for the Surgery of Trauma Practice Management Work Group of the United States[14] recommends that patients receive a single preoperative dose of a wide-spectrum antibiotic against aerobic and anaerobic microorganisms if no hollow viscus lesion is found. In the presence of this lesion, however, antibiotic administration should be extended for 24 hours. These recommendations have been evaluated by other groups.[15] We found that prophylactic administration of an antibiotic protects against the development of intra-abdominal infection. Protection was also afforded by the intraoperative use of antibiotics. In the absence of their prophylactic administration, patients who received no antibiotics had the highest risk of infection.

We found that a diminution of RTS was associated with a marked increase in the risk of intra-abdominal infection. It is probable that tissue hypoperfusion and hypoxia give rise to immunosupression that increases susceptibility of patients to bacteria and leads to the development of infection.[16]

A low percentage of patients with an elevated ISS was found, probably because many individuals with severe trauma die at the scene or during transportation to the hospital. This subgroup of patients, especially those with an ISS greater than 20, are known to be at high risk of development of pneumonia and at greater risk of MOF; in addition, their mortality rate is higher.[17,18]

We found that the probability of intra-abdominal infection is 4.7 times higher when the ATI score is greater than 24. In the logistic regression analysis, this was an independent risk factor for the development of infection, and these findings are in agreement with those of other authors.[6,12,17]

Some authors have found a relationship between hypotension and infection but without a statistically significant difference[12]; this is probably due to insufficient size of the samples.

The amount of third-space fluid correlates with the duration and severity of hypovolemic shock. This state of hypoperfusion and hypoxia is a possible explanation for the high incidence of infection. Prolonged hypotension, in our series, increased the risk of infection 3-fold.

Blood transfusion has been described as an independent risk factor for the development of infections in trauma patients.[9,18] The mechanisms responsible for transfusion-related immunological alterations have not been completely elucidated. Several bioactive substances such as cytokines, histamine, and proinflammatory lipids accumulate during red blood cell storage.[19] In agreement with other studies,[9,18] we found a clear association between the number of units of total blood transfused and the risk of infection.

Information on abdominal cavity contamination as a risk factor for development of abdominal infection is limited, probably because of the difficulty of its measurement. In our research, a quadrant-based classification system was used. Bivariate analysis showed that the probability of development of intra-abdominal infection increased with the number of contaminated quadrants. In the logistic regression analysis, abdominal cavity contamination was evaluated as a dichotomous variable. Its presence was independently associated with intra-abdominal infection, increasing the risk by 2.6 times.

The risk of development of infection is known to be higher in patients with programmed surgical interventions when such interventions are prolonged.[20] In this group of patients undergoing operation because of trauma, a dose-response relationship was found between surgical time and intra-abdominal infection, ie, the risk of infection increases as surgical time lengthens.

The probability of infection in patients with splenic trauma is directly related to the number of associated lesions. During the early postoperative period, splenectomy resulting from trauma does not affect the incidence of severe infectious complications, unless splenic trauma is combined with colonic, pancreatic, or cranial trauma or with fractures of the extremities.[21] We found that the risk of intra-abdominal infection increases with splenectomy; however, after logistic regression, this kind of intervention does not appear to be an independent risk factor. This indicates that the severity of trauma and the associated lesions have greater influence on the development of infections.

Adequate use of drains prevents abdominal complications, whereas improper use leads to them. In this study, the use of drains was a risk factor for infection.

We found that colostomy increases the risk of intra-abdominal infection. This procedure is the result of an intraoperative decision that very likely reflects an attempt on the part of the surgeon to prevent complications in view of the severity and local extension of the lesions.

In their study on the factors associated with infection in patients with colonic penetrating trauma, Dente et al[10] found that some kind of infection (including superficial and deep incisional surgical site infection, as well as other nosocomial infections) developed in 4.1% of patients with ostomies. In contrast, only 14% of patients without ostomies experienced this complication.

Performing multiple surgical procedures has been associated with higher risk of nosocomial sepsis in patients undergoing elective[22] or trauma-related surgery.[9]

In our cohort, 315 operations or related procedures were performed on 293 patients. Of these, 171 (54.3%) were thoracostomies that did not constitute a risk factor for the development of intra-abdominal infection.

Trauma damage-control surgery, abdominal packing with compresses, and open abdomen are surgical strategies that have allowed improved survival of selected patients with severe hepatic trauma and other serious intra-abdominal lesions associated with coagulopathy, acidosis, and hypothermia.[23] However, organ failure and septic complications may develop in survivors. Immunologic and septic consequences of surgery by stages are not yet thoroughly understood. Peritoneal fluid of patients in whom packing has been performed accumulates endotoxins and inflammatory mediators, even though cultures may be sterile. Accumulation of such substances contributes to the systemic inflammatory response.[24] Abikhaled et al[25] demonstrated that abdominal packing for longer than 72 hours increases the incidence of septic complications. In our series, the patients who underwent reoperation (58 patients [7.6%]) had major risk of intra-abdominal infection.

It was not possible to evaluate the development of infection as a function of the duration of packing because of the limited number of patients that required it for longer than 48 hours. Packing compresses should be withdrawn as soon as possible once the patient is hemodynamically stabilized and acidosis, coagulopathy, and hypothermia have been corrected. However, the moment for reoperation varies widely, precisely because of the difficulty of achieving those aims during reanimation in the ICU.

It has been shown that the stay in the ICU increases the risk of development of nosocomial infection.[22] Our results agree with this fact. Other studies[26] show this association indirectly, citing evidence that the requirement of mechanical ventilation and the use of central vascular catheters are risk factors for the development of infection in patients hospitalized because of trauma.

Our results confirm previous findings[26] of an association between the development of infection in trauma patients and the length of their hospital stay. This may indicate that infection extends hospitalization or that a prolonged hospital stay increases the likelihood of infection.

Many factors associated with a higher risk of development of intra-abdominal infection correlate with the severity of the lesion. Consequently, it may be difficult to identify independent risk factors. Nevertheless, by means of a multivariate logistic regression analysis, we identified the following such factors for the development of intra-abdominal infection in this group of patients: an ATI greater than 24, abdominal cavity contamination, and admission to the ICU. Although this model adjusts well (Nagelkerke $R^2=0.6$) and predicts 90% of the events, it should not be used as the only predictor, because it explains only 30% of the variability of the dependent variable. Other factors, among them the nutritional and immunologic states, not measured in this study, may intervene in the development of intra-abdominal infection.

CONCLUSIONS

The development of intra-abdominal infection in patients undergoing operation because of abdominal trauma is a complex phenomenon resulting from multiple risk factors encountered during the preoperative, intraoperative, and postoperative periods. Multivariate logistic regression analysis allowed us to identify an ATI greater than 24, the contamination of the abdominal cavity, and admission to the ICU as independent risk factors for the development of intra-abdominal infection. Therefore, we recommend early identification of those patients at greater risk of development of this complication, so that early interventions may be performed to minimize secondary morbidity and mortality.

Preoperative antibiotics should be administered to every patient with abdominal trauma who will undergo laparotomy. Patients at greater risk should undergo early and aggressive reanimation in an attempt to diminish the number of transfused blood units and the possibility of intraoperative hypotension. Ostomy, splenectomy, and drains should be based on protocols. Finally, a careful selection of patients for damage-control surgery, open abdomen, and packing should be ensured.

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Invited Critique

Morales and colleagues have performed a prospective descriptive study aimed at determining the incidence of, and risk factors for, postlaparotomy intra-abdominal infection in trauma patients. To accomplish this, the authors selected 21 demographic and perioperative variables and assessed their impact on intra-abdominal infection in 762 patients. Ideally, these results would then enable the trauma surgeon to more readily identify the patient at high risk for postoperative intra-abdominal infection, and thus perhaps to institute some change in his or her practice that would decrease the incidence of this complication or prevent it entirely. However, multivariate statistical analysis revealed that only an ATI greater than 24, multiquadrant contamination, and admission to the ICU were significant predictors of postlaparotomy intra-abdominal infection.

This study confirms what is already intuitively obvious: more severely injured patients (those having a high ATI) are more likely to require ICU care and more likely to sustain postoperative complications (increased incidence of intra-abdominal infection). Unfortunately, each of these 3 risk factors is beyond the trauma surgeon's control; thus, the authors have provided us with little practical information that will benefit our patients. Perhaps the 10.6% postoperative intra-abdominal infection rate cited by the authors cannot be improved, given the limitations placed on today's trauma surgeon (established peritoneal contamination, shock, multiple-organ injury, etc). On the other hand, there may be additional perioperative variables the authors did not evaluate in their study that could be manipulated by the trauma surgeon to reduce the incidence of intra-abdominal infection. For example, do the specific organ injured and the method chosen to repair it affect infection rates? What is the impact of technical errors (anastomotic leaks, missed injuries, recurrent hemorrhage) on infection rate? Are there additional ICU variables (length of antibiotic treatment, need for inotropic support, impact of shock, presence of respiratory and renal dysfunction, and timing, type, and duration of nutritional support) that may influence the development of postoperative intra-abdominal infection? Large prospective studies, such as that undertaken by Morales and colleagues, offer us the best opportunity to develop new approaches to complex and challenging clinical problems. Unfortunately, despite the immense effort expended by these authors, that opportunity remains largely unfulfilled.

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