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Original Research Article

Clinical study of intra-abdominal pressure in the acute surgical abdomen

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ABSTRACT

Background: Intra-abdominal pressure (IAP) is the steady-state pressure concealed within the abdominal cavity. Early recognition of rising abdominal pressure is critically important, because it allows prompt intervention which will prevent Abdominal compartment syndrome (ACS) from developing, leading to a much better prognosis for the patient. This prospective case-control study was aimed at characterisation of this entity in the commonly encountered acute surgical abdomen i.e. perforation peritonitis, intestinal obstruction and the blunt abdominal trauma. The stress was laid upon the detection of the intra-abdominal pressure in the patients and the effect of this entity upon the routinely available clinical and laboratory parameters of organ functions. The organ systems studied were the renal, cardiovascular and the pulmonary systems. The clinical outcome was also analysed.
Methods: This is a prospective study conducted in Rajendra Institute of Medical Sciences, Ranchi, Jharkhand over a period of one and half year (January 2014 to June 2015). A total of 120 patients were studied, including 30 as controls. The intra-vesicular pressure was measured in all the subjects, which indirectly gives intraabdominal pressure.
Results: Initial intra-abdominal pressure ranged from 0-31 cm of saline with the mean of 13.77±8.46. The mean values of the intra-abdominal pressure in the study groups i.e acute surgical cases were found to be significantly higher, as compared to that of the control group ($p<0.01$). Highest mortality was observed in the IAP range of >25 cm of saline (33.33%, 4 out of 12).
Conclusions: Raised intraabdominal pressure significantly affects outcome and increases mortality.

Keywords: Abdominal compartment syndrome, Intra-abdominal pressure, Intra-abdominal hypertension, Intra-vascular pressure

INTRODUCTION

Intra-abdominal pressure (IAP) is the steady-state pressure concealed within the abdominal cavity.[1] While the abdominal wall has elasticity, if intra-abdominal volume increases due to fluid, gas, pus, tissue oedema, high pressure leads to reduced blood flow and tissue ischemia which contributes to multiorgan failure. It is affected by body weight, posture, tension of abdominal muscles, and movement of the diaphragm.[2-4] Intra-abdominal hypertention(IAH) defined as an IAP ≥12 mmHg, and abdominal compartment syndrome as an IAP ≥ 20 mmHg combined with the failure of a new organ.[1,5] The prevalence of IAH on admission to the intensive care unit (ICU) ranges from 31 to 58.8% and the incidence increases with the length of ICU stay.[4,6,7] In healthy individuals IAP ranges from sub-atmospheric to 5 mmHg and fluctuates with respiration, body mass index and

activity. For the measurement of intra-abdominal pressure, the various methods can be classified as;

- Direct
- Indirect[8]

Table 1: Grading schemes for elevated intra-abdominal pressure.

Grade	WSACS definition[13]mm Hg[a]	Burch[11]/Meldrum[12] classification, mm Hg[b]
I	12-15	10-15
II	16-20	15-25
III	20-25	25-35
IV	>25	>35

WSACS, World Society of the Abdominal Compartment Syndrome; [a]Pressure measured with zero at midaxillary line; [b]pressure measured with zero at pubic symphysis.

However, of all the methods the intra-vesicular pressure has been accepted as gold standard to determine the intra-abdominal pressure in the clinical setting.[9,10] The reference standard for intermittent IAP measurements is via the bladder with a maximal instillation volume of 25 mL of sterile saline.

IAP should be expressed in mmHg and measured at end-expiration in the complete supine position after ensuring that abdominal muscle contractions are absent and with the transducer zeroed at the level of the midaxillary line. Once measured, the pressure is graded. Table 1 compares the current World Society of the Abdominal Compartment Syndrome grading classification of elevated IAP to the previously widely used Burch/Meldrum classification.[11,12]

Diagnosis

Table 2: Grading of the intra-abdominal pressure (Burch et al) and Recommendations.[11]

Grade	Bladder pressure (cm of H_2O	Recommendations
1.	10-15	No decompression needed
2.	15-25	Close monitoring of patients, decompression if needed
3.	25-35	Decompression mandatory
4.	>35	Urgent decompression, life threatening

The clinical pictures of raised intra-abdominal pressure is characterized by decreased cardiac output, hypoxia progressively increasing airway pressure and oliguric renal failure in a patient with tensely distended abdomen.[4,5]

Early recognition of rising abdominal pressure is critically important, because it allows prompt intervention which will prevent ACS from developing, leading to a much better prognosis for the patient.

Treatment

Decompression is the mainstay of treatment in those patients with significant rise in the intra-abdominal pressure. While surgical decompression is unquestionably a rapid and definitive treatment, if accessible free fluid is present in the abdomen, percutaneous catheter drainage has been reported to be a successful treatment for ACS (Table 3).[14-18]

METHODS

This is a prospective study conducted in Rajendra Institute of Medical Sciences, Ranchi, Jharkhand over a period of one and half year, (January 2014 to June 2015).

Patients of acute intestinal obstruction, non-traumatic intestinal perforation peritonitis and blunt trauma abdomen. 30 patients were studied from each group. Another group of 30 subjects with conditions other than the acute surgical abdomen who had indwelling Foley's catheter, as a part of their management protocol, were taken as controls.

Exclusion criteria

- Patients with concurrent thoracic or lower urinary tract injuries, in cases of blunt trauma abdomen
- Those with bladder dysfunctions
- Patients with preexisting cardiac failure
- Patients with concurrent head injury and spinal injury in cases of blunt trauma abdomen.

Evaluation

The intra-vesicular pressure was measured in all the subjects by way of an indwelling Foley's catheter, attached to a hand held Saline manometer. All such measurements were recorded on three consecutive days.

Statistical analysis

The observations were statistically analysed using the paired and unpaired 't' test, Chi-square test with Yate's correction, Pearson's correlation coefficient and the simple linear regression analysis.Innova test was used to see the significant difference among the groups.For multiple comparision analysis POST HOC test,TUKEY test was applied to see the significant difference between the groups. For statistical analysis SPSS 16.0 also used.

This study did not involve any interventional procedure as such and the usual protocol of the patient management was observed. However, an informed consent was taken from all the subjects.

RESULTS

A total of 120 patients were studied, including 30 as controls. Group I, II, III and IV are cases of non-traumatic perforation peritonitis, intestinal obstruction, blunt trauma abdomen and control respectively. Each group contains 30 patients.

Age

Age ranged from 12 to 78 years with the mean of 39.27±15.625. Age distribution according to the various study group is shown in Table 3.

Table 3: Age distribution of the study population.

Age group	I (%)	II (%)	III (%)	IV (%)	Total
10-19	2 (6.67)	3 (4)	4 (24)	1 (12)	10
20-29	10 (33.33)	7 (23.33)	7 (23.33)	5 (16.67)	29
30-39	5 (16.67)	2 (6.67)	9 (30)	8 (26.67)	24
40-49	5 (16.67)	5 (16.67)	6 (20)	7 (23.33)	23
50-59	5 (16.67)	3 (10)	4 (13.33)	4 (13.33)	16
60-69	3 (10)	7 (23.33)	0	3 (10)	13
70-79	0	3 (10)	0	2 (6.67)	5
Total	30	30	30	30	120

Clinical findings

Non-traumatic perforation peritonitis

Out of the 30 patients of this group, those with duodenal ulcer perforation constituted the major bulk (50%, 15 out of 30). 2nd most comman cause of perforation in this population is ileal perforation,cause may be enteric fever. The details are as shown in Figure 1.

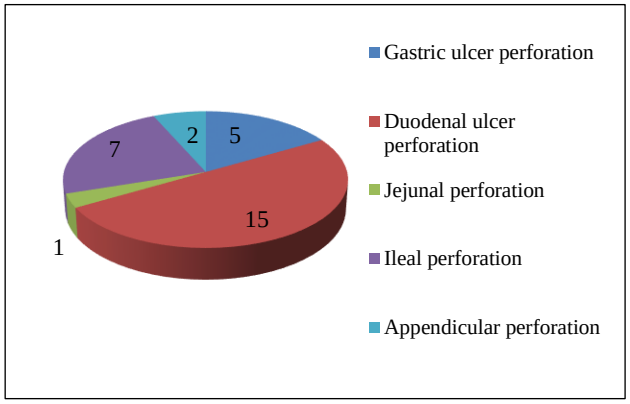

Figure 1: Clinical findings in the subjects of Group I.

Intestinal obstruction

64% of the obstructed patients had small bowel obstructions and remaining had large bowel obstructions, due to various pathology as detailed in Table 4.

Blunt trauma abdomen

In this group, solid organ injury was noted in 16 patients (64%), hollow viscus injury in 8 patients (32%), 3 cases were kept in Others, in which 1 patient had gallbladder injury, 1 patient had Ileal as well as jejunal tear another had mesenteric tear only. Jejunal injury was the most comman injury (9 out of 30, 30%) seen in this group followed by liver injury (8 out of 30, 26.67%). detailed in Figure 2.

Table 4: Clinical findings in the subjects of Group II.

Finding	Number of cases	%
Colon mass	4	13.33
Adhesive band	4	13.33
Post-operative adhesion	3	10
Koch'abdomen	2	6.67
Sigmoid volvulos	6	20
Ileal stricture	3	10
Obstructed inguinal hernia	4	13.33
Rectal mass	1	3.33
Maecal's diverticulum	3	10

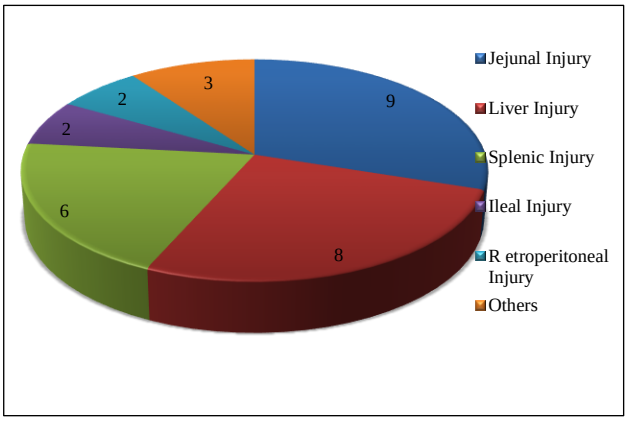

Figure 2: Clinical findings in the subjects of Group III.

Controls

Control group studied is group of 30 subjects with conditions other than the acute surgical abdomen who had indwelling Foley's catheter, as a part of their management protocol,

Intra-abdominal pressure

Initial intra-abdominal pressure ranged from 0-31 cm of saline with the mean of 13.77±8.46. The group wise distribution of the intra-abdominal pressure and the 'p' values of their difference (by unpaired 't' test) is shown in Table 5.

Table 5: Details of the presentation IAP in the various groups and 'p' value between groups.

IAP (cm of saline)				'p' value between groups
Group	**Range**	**Mean±SD**	I-II	0.169
I	11.5-31	20.73±4.87	I-III	0.000*
II	10.5-29	18.38±5.48	I-IV	0.000*
III	8-31	14.00±4.44	II-III	0.000*
IV	0-6	1.96±1.92	II-IV	0.000*
Total	0-31	13.77±8.46	III-IV	0.000*

* 'p' significant.

Table 6: Group wise categorization of the intra-abdominal pressure.

			Group				Total
			I	**II**	**III**	**IV**	
IAP	< 10	Count (%)	0 (0)	0 (0)	2 (6.7)	30 (100.0)	32 (26.7)
	10-15	Count (%)	4 (13.3)	9 (30.0)	17 (56.7)	0 (0.0)	30 (25.0)
	15-20	Count (%)	8 (26.7)	9 (30.0)	9 (30.0)	0 (0.0)	26 (21.7)
	20-25	Count (%)	12 (40.0)	7 (23.3)	1 (3.3)	0 (0.0)	20 (16.7)
	>25	Count (%)	6 (20.0)	5 (16.7)	1 (3.3)	0 (0.0)	12 (10.0)
Total		Count (%)	30 (100.0)	30 (100.0)	30 (100.0)	30 (100.0)	120 (100.0)

Table 7: Comparison of intra-abdominal pressure within the groups on three days.

Groups	IAP (cm of saline)			'p'		
	Day 1	**Day 2**	**Day 3**	**D1-D2**	**D1-D3**	**D2-D3**
I	20.73±4.87	10.28±2.42	7.43±2.45	<0.001*	<0.001*	<0.001*
II	18.38±5.48	10.10±2.29	8.04±2.20	<0.001*	<0.001*	=0.001*
III	14.00±4.44	10.17±2.28	8.55±2.21	<0.001*	<0.001*	=0.008*

* 'p' significant.

Thus, the control group mean intra-abdominal pressure was found to be 1.96±1.92 cm of saline in this study. And the mean values of the intra-abdominal pressure in the study groups (I, II and III) were found to be significantly higher, as compared to that of the control group ($p<0.01$). Further, the difference in the mean values between Groups I and III and Groups II and III were found to be significant ($p<0.05$), but not between the groups I and II.

The intra-abdominal pressure at presentation could be categorized in different ranges, as shown in Table 6.

The serial intra-abdominal pressure estimation showed a significantly decreasing trend on three successive days of measurements, in all three study groups. Paired 't' test was used to study the difference (Table 7). All the patients in group I underwent laparotomy, while 5 patients in group II and 4 patients from group III were managed conservatively.

The trend of the intra-abdominal pressure was studied separately in patients, who did not undergo laparotomy. There was a drop in the intra-abdominal pressure in group III patients, which achieved statistically significant levels by day 3 ($p<0.05$). In group II, a 34 years female with obstructing carcinoma of the anorectum was relieved of the obstruction on conservative treatment and his intra-abdominal pressure dropped subsequently. However, the overall drop in the intra-abdominal pressure of group II patients, treated conservatively was not statistically significant.

The trend of the intra-abdominal pressure can be represented by the graphs as in Figure 3.

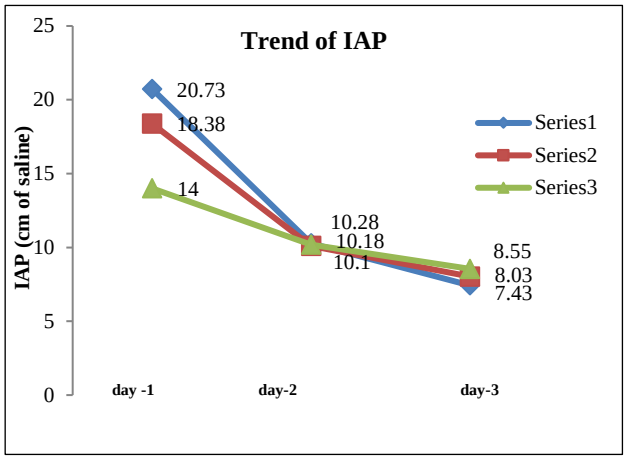

Figure 3: The trend of the intra-abdominal pressure.

Outcome

There were total of 19 deaths in the study. Group wise distribution of the outcome is as shown in Figure 4.

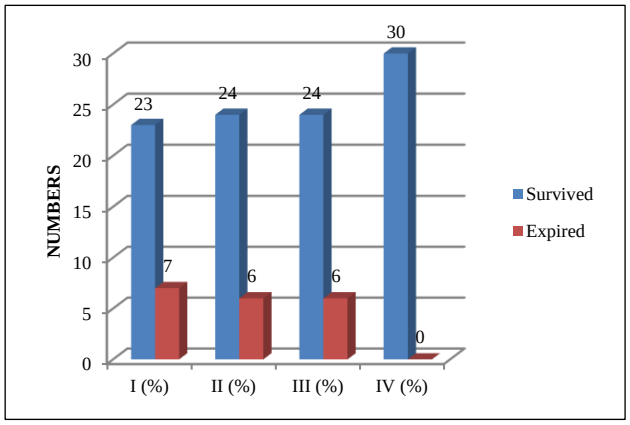

Figure 4: Group wise distribution of the outcome.

Highest mortality was observed in the perforation group (23.33%; 7 out of 30), followed by the Obstruction and blunt trauma group (20%; 6 out of 30). The details of the death in the different groups in shown in Figure 4.

IAP and outcome

The initial intra-abdominal pressure was studied to be compared with the outcome in the study groups (Group I, II and III). The results are shown in Figure 5.

Highest mortality was observed in the IAP range of 25-35 cm of saline (33%, 4 out of 12), followed by IAP range of 15-25 cm of saline (26%, 12 out of 46). It is obvious from the observation that as intra-abdominal pressure increased there was an increase in percentage mortality.

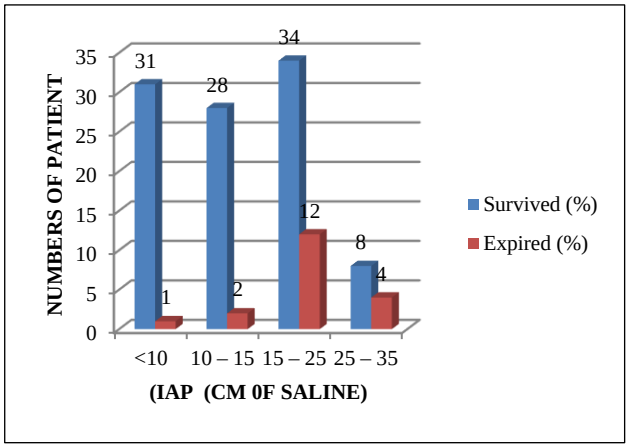

Figure 5: Comparison between the IAP and the outcome in the study.

Prediction of the mortality in the study groups

The different variable was studied to predict the mortality by Chi-square test with yate's correction (Table 8). In our study age, blood urea, serum creatinine and intraabdominal pressure were studied to predict mortality.

Table 8: Prediction of the mortality in the study groups.

	Age (years)		Blood urea	(mg%)*	IAP(cm of saline)*		Serum creatinine (mg%)*	
	>60	≤60	>40	≤40	>15	≤15	>1.4	≤1.4
Expired	3	16	14	5	16	3	12	7
Survived	9	92	30	66	38	63	17	79
X^2	X^2 = 0.841		X^2 = 12.090		X^2 = 14.023;		X^2 = 17.373;	
P	p>0.001		p=0.001'		p<0.001		p<0.001	

(Please note that B urea and S creatinine values were available only for 115 patients; hence calculations have been done on 115 patients only) * All the variables are the presentation values. P≤ 0.001: Significant

Significant mortality was associated with IAP: >15 cm of saline, Blood urea>40 mg% and serum creatinine >1.4 mg%.

Correlation of the intra-abdominal pressure

The relationship between the presentation intra-abdominal pressure and the abdominal girth, and the

different organ functions were studied, by way of the simple linear regression, using the Pearsons'scorrelation coefficient (Table 9).

Table 9: Correlation of the intra-abdominal pressure.

Correlation coefficient			
Variables	**Group I**	**Group II**	**Group III**
IAP-SB	0.175#	-0.180	0.335#
IAP-DB	0.253#	-0.099	0.134#
IAP-MBP	0.296#	-0.147	0.367*
IAP-RR	0.178#	0.247#	0.377*
IAP-pH	-0.266	-0.169	0.279#
IAP-PaO_2	-0.223	-0.114	-0.436
IAP-SpO_2	-0.179	-0.349	-0.262
IAP-BU	0.355#	0.171#	0.414*
IAP-SCr	0.201#	0.459*	0.314#

DISCUSSION

IAP has been measured since the 19th century. Ever since then, its importance has been recognized recently. Since the mid-1990s it was known that IAH could develop without abdominal trauma and numerous studies have measured IAP, examined its clinical outcomes, and classifications.[23] Intra-abdominal pressure has interested many clinicians and the researchers in the recent years. The stress has been laid upon the prospective characterization and the selective management of this entity, keeping in view the diverse physiological disturbances, most of the clinical studies were carried out in patients of abdominal trauma with intraperitoneal haemorrhage and those post-operative patients, who developed features of raised intra-abdominal pressure due to various causes.

The present prospective case-control study was aimed at characterization of this entity in the commonly encountered acute surgical abdomen i.e. perforation peritonitis, intestinal obstruction and the blunt abdominal trauma. The stress was laid upon the detection of the intra-abdominal pressure in the patients and the effect of this entity upon the routinely available clinical and laboratory parameters of organ functions. The organ systems studied were the renal, cardiovascular and the pulmonary systems. The clinical outcome was also analysed.

Regarding the estimation of the intra-abdominal pressure, we used only the intra-vesicular pressure. Kron et al have observed that the bladder pressure can accurately measure the IAP at the range of 5 to 50 mm of Hg.[9] Lacey et al have shown the significant correlation of the intra-vesicular ($r > 0.85$; $p < 0.001$) and the inferior vena caval pressure ($r > 0.87$; $p < 0.001$) to the IAP.[19] In this study, for the purpose of simplicity and convenience we have used 'cm of saline'. The interconversion could be done as, 1mmHg = 1.36 cm of saline.

In the present study, the mean intra-abdominal pressure of the control group was found to be 1.96±1.92 cm of saline. This could be explained on the basis, that, the voluntary abdominal muscle contraction can also influence the pressure. Moreover, the control group in this study was consisted of the patients as detailed previously and not the normal subjects.

However even in our study, the intra-abdominal pressure readings of the study groups (I, II and III) were found to be significantly raised when compared to the control group ($p<0.01$). There was significantly lower intra-abdominal pressure, at presentation, in the patients of blunt trauma abdomen (Group III), compared to those of group I and II. When followed up with the serial measurements, the intra-abdominal pressure readings of all the groups were almost equal by the third day (Figure 5).

The trend of the intra-abdominal pressure in conservatively managed patients was studied. It was found that there was no statistically significant change in the intra- abdominal pressure in Group II patients on successive days. But the steep slope of the graph (Figure 5) resulted, as a patient of obstructing carcinoma anorectum got relieved of the obstruction spontaneously. Also as there were only two such patients studied in this group, the result could be misleading. Whereas in group III, 8 such patients were studied, there was statistically significant decrease in the intra-abdominal pressure by day 3 only ($p<0.005$).

Study analysed the outcome with respect to the intra-abdominal pressure. It was found that there was higher mortality in those patients, who had IAP >15cm saline. The Chi - square test was applied to substantiate the same and the value of X2 was found to be 14.023 ($p<0.001$), which is significant. Thus, this study observations support the grading system of the intra-abdominal pressure (Table 2) and the recommendations, in the sense that those patients, who have recording of the intra-abdominal pressure >15cm saline need to be considered for decompression.[11]

The limitation of the above statement is that the intra-abdominal pressure alone need not be the deciding factor. But patients' other clinical and laboratory parameters should also be taken in to consideration and proceed accordingly. The higher grades of peritonitis and septicemia would definitely call for laparotomy, even if the IAP is not significantly raised. Similarly, in patients of blunt trauma abdomen with intraperitoneal haemorrhage who have altered physiological status, should be operated even if the IAP is not significantly raised. Simon et al 20 in their study have also noted that in the clinical scenario of haemorrhagic shock and resuscitation, avoidance of even the moderate levels of increased intra-abdominal pressure by prophylactic decompression, improves the outcome.

Decompression could be a formal laparotomy or even the insertion of a flank drain, which could result in the dramatic relief from the IAP and the consequences there with

Correlation between the intra-abdominal pressure and the different organ functions

In this study showed the adverse effects of raised IAP on some organ functions, whereas some other parameters failed to correlate significantly with variations in IAP. In Group I patient IAP shows significant correlation with Heart Rate (HR) P<.05). In Group III patient significant correlation was seen between IAP and blood urea (BU), respiratory rate (RR), Mean blood pressure (MBP), (P<.05). In Group II significant correlation was seen only between IAP and Sr. Creatinine, (p<.05). This study has failed to demonstrate significant correlation between the intra-abdominal pressure and the different organ functions, except what mentioned above.

Kron et al, in a study of 11 postoperative patients observed that all of them had the intra-abdominal pressure >30 mmHg and developed oliguria.[9] However, the haemodynamic measures (Pulmonary capillary wedge pressure (PCWP), Cardiac index and mean blood pressure) remained unchanged even at that pressure. The administration of loop diuretics and dopamine did not reverse the oliguria in those patients, but the abdominal decompression resulted in immediate diuresis. Iberti et a110, in canine model have demonstrated that at an IAP >25 mmHg, there are significant changes in the haemodynamic, respiratory, renal and metabolic functions. They observe the decrease in cardiac output and the stroke volume with the raised IAP.

There was significant increase in the systemic vascular resistance, central venous pressure and the pulmonary capillary wedge pressure. However increasing IAP did not significantly change the mean arterial pressure. The pulmonary effects of increased IAP included decreased PaO2, increased airway pressure and marked ventilation/perfusion abnormality. The clinical case reports and the studies support the similar physiologic effects as those in the animal models.[21]

In this study also, the increasing IAP did not show significant correlation with the mean blood pressure except in group III (no significant change in the mean blood pressure) as demonstrated by Iberti et al. The possible explanation for the discrepancy with respect to the previous studies, could be that, the present study has been conducted in a small sample population. No complex monitoring gadgets were used in the present study. As the very purpose of this study was to evaluate the easily available parameters to predict the physiological derangements and thereby help in the early decision making as per need.

Prediction of the outcome

In the present study, significant mortality was observed with IAP >15cm saline, and serum creatinine >l.4mg% blood urea >40 mg%. Meldrum et al have observed that the IAP when exceeds 30mmHg, heightens the risk of multisystem organ failure and subsequent death.[22] Sugrue et al, in a prospective study of 100 patients have demonstrated that there were significant number of deaths (72% of the total deaths) if IAP ≥20mmHg (X215.7; p<0.01).[14]

In the present study, there were 19 deaths (13.33%) from the study groups, of which 7 had perforation peritonitis, 6 had intestinal obstruction and 6 had sustained blunt abdominal trauma. Total 19 patients died, out of which 1 death was on 2nd post-operative day 6 on 3rd day of admission and rest within first 7 days of admission. Patient who died within three days of admission were not able to maintain their blood pressure even on adding ionotropes and has other comorbid conditions, along with electrolyte imbalance While those who died after the 3rd postoperative day (12 patients) expired due to septicemia, in addition to the Acute respiratory distress syndrome (ARDS) and other systemic failure. In this study, a total of 9 patients were managed conservatively, 5 of obstruction and 4 of blunt trauma. In this study, high mortality was seen in patients of perforation peritonitis (23.3%, 7 out of 30). Probable reason may be delayed presentation, septicemia, poor nutritional status, etc.

CONCLUSION

The mean IAP of the control group was 1.96±1.92 cm of saline. Whereas the mean IAP of groups I, II and III were 20.73±4.87, 18.38±5.48 and 14.00±4.43 cms of saline respectively.

The IAP score of group III (blunt trauma abdomen) were less than that of groups I and II.

Highest mortality was observed in the perforation group (23.33%; 7 out of 30), followed by the obstruction and blunt trauma group (20%; 6 out of 30). Highest mortality was observed in the IAP range of >25 cm of saline (33.33%, 4 out of 12). Thus, in this study, significant mortality was associated with IAP: >15 cm of saline, Blood urea>40 mg% and serum creatinine >1.4mg%.

The serial IAP estimation showed a significant decreasing trend on subsequent days in all group,when the operated and conservatively managed patients were combinedly studied. The significant correlation between the IAP and the blood urea was seen in group III (p<0.05, r=0.414) only. Decision to intervene surgically is not based on IAH alone bue rather on the presence of organ dysfunction in association with IAH.

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Conflict of interest: None declared
Ethical approval: The study was approved by the institutional ethics committee

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