VENOUS PHASE DIAMETER OF INFERIOR VENACAVA ON COMPUTED TOMOGRAPHY- A PREDICTOR OF HYPOTENSION IN BLUNT ABDOMINAL TRAUMA -ONE YEAR HOSPITAL BASED OBSERVATIONAL STUDY

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KLE ACADEMY OF HIGHER EDUCATION AND RESERCH, BELAGAVI, KARNATAKA

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This is to certify that the dissertation entitled **“VENOUS PHASE DIAMETER OF INFERIOR VENACAVA ON COMPUTED TOMOGRAPHY- A PREDICTOR OF HYPOTENSION IN BLUNT ABDOMINAL TRAUMA ONE YEAR HOSPITAL BASED OBSERVATIONAL STUDY”** is a bonafide research work done by **REG NO BS0117006.**

DR. ASHWIN PATIL
M.D. RADIO-DIAGNOSIS
Professor and Head,
Department of Radio Diagnosis,
J. N. Medical College,
Nehru Nagar, Belagavi – 10

Date:
Place: Belagavi

Dr. N.S. MAHANTASHETTI
M. D. PEDIATRICS
Principal,
J. N. Medical College,
Nehru Nagar, Belagavi – 10

Date:
Place: Belagavi

PLAGIARISM CERTIFICATE

JAWAHARLAL NEHRU MEDICAL COLLEGE
(A constituent unit of KLE Academy of Higher Education & Research Deemed-to-be University)
Accredited 'A' Grade by NAAC (2nd Cycle) Placed in Category "A" by MHRD (GoI)
Nehru Nagar, Belagavi-590 010, Karnataka-India

Website : http/www.jnmc.edu
E-Mail : Principal@jnmc.edu
Office :+91-(0)831 2471350
FAX :+91 (0)831-2470759

Ref. No. : MDC/PG/ Date : 30.9.19

To,

Postgraduate Student,
Department of Radiology,
2017-18 Batch,
J. N. Medical College,
Belagavi.

Sub: Acceptance Letter

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Coordinator
Department of Radiology
J. N. M. C. Belagavi.
Dr. PRADEEP GOUDAR
KMC No. 83170

Chairman,
Antiplagiarism Committee

KAHER J.N. MEDICAL COLLEGE BELAGAVI

ABSTARCT

INTRODUCTION: Blunt abdominal trauma is one of the important contributors to morbidity and mortality. Studies have indicated that the incidence of blunt abdominal trauma has been increasing in the past decade. Since the burden of blunt abdominal trauma is more in Low- and Middle-income countries such as India, it calls for the development of various rapid diagnostic modalities to aid in early diagnosis, for faster initiation of treatment and for reducing the preventable mortality.

AIMS & OBJECTIVES: The current study was aimed at assessing the diameter of IVC on the axial section of the CT scan of the abdomen as a predictor of hypotension in blunt abdominal trauma.

MATERIALS & METHODS: The current study was a cross sectional study, conducted in the department of Radiodiagnosis at KLE's Dr.Prabhakar Kore Hospital & MRC, Belagavi. A total of 30 blunt abdominal trauma patients affected by blunt abdominal trauma were included by universal sampling method. Transverse: Anteroposterior ratio of the IVC was measured infrarenally. The normal cut off value of ratio was considered as 1.9. We considered a ratio of > or = 1.9 as flat IVC and that <1.9 -as non- flat IVC. The sensitivity, specificity and predictive values of flat IVC in detecting hypotension were assessed by using IBM SPSS statistical software.

RESULTS: This study included 30 subjects with a history of blunt abdominal injury with a mean age of 26.93 ± 11.51 years for analysis. Majority of subjects were in the age group of 21 to 40 years. There was a significant male preponderance as 83.3% of the study subjects were men. All the 30 patients involvement of the solid organs, among whom 16(53.3%) had splenic injury, 15(50%) had liver injury, 4(13.3%) had pancreatic injury and 5(16.7%) had kidney injury. Among the splenic injury patients, major proportion were grade III(37.5%) and grade IV (37.5%) injuries. The percentage of Grade II and Grade III (n=5, 33.33% each) injuries were higher among liver injury patients. The percentage of grade III (n=2,50%) injury was greater among patients with pancreatic injury compared to Grades II and IV (n=1, 25% each). Whereas, the percentage of grade I and II (n=2, 40% each) injuries was equal among patients with kidney involvement. Among the study population 23(76.7%) had flat IVC 28(93.3%) had hypotension and 23(76.7%) had both hypotension and flat IVC. Flat IVC had sensitivity of 82.14% (95% CI 63.11% to 93.94%), specificity of 100.00% (95 CI 15.81% to 100%) in detecting hypotension. The positive predictive value was 100.00% (95 CI 85.18% to 100%), Negative predictive value was 28.57% (95 CI 3.67%to 70.96%), and the total diagnostic accuracy was 83.33% (95 CI 65.28%to 94.36%).

CONCLUSIONS: Flat IVC on CT could be of value in predicting hypotension among blunt abdominal trauma patients. Perhaps, this finding could serve the treating physician as an aid in early diagnosis and management to prevent mortality in such patients.

LIST OF ABBREVIATIONS

GLOSSARY	ABBREVIATIONS
AP	Anteroposterior
AUC	Area Under the Curve
AVI	Abdominal Vascular Injuries
BAAI	Blunt Abdominal Aortic Injury
BAT	Blunt Abdominal Trauma
BSI	Blunt Splenic Injury
DCL	Damage control laparotomy
HSC	Hypovolemic Shock Complex
HVI	Hollow Viscus Injury
IAVI	Intra-Abdominal Vascular Injuries
IVC	Inferior Vena Cava
NOM	Non-Operative Managemennt
RTAs	Road Traffic Accidents
SOI	Solid Organ Injury
TBI	Traumatic Brain Injury
WHO	World Health Organisation

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INTRODUCTION

Trauma and resultant injuries can be considered as a major global cause of mortality. According to the World Health Organization (WHO), injuries result in the death of about 5 million individuals annually across the globe. Almost 9% of the worldwide mortality is due to trauma. According to the reports released by the Centre for Disease Control and Prevention, each year, around 2,14,000 individuals lose their lives because of injury-related mortality. This translates to about 1 person per 3 minutes.[1]

However, the morbidities due to injuries vastly outnumber the mortality rates. For every person who dies due to trauma, many more are hospitalized due to injuries.CDC states that for each person who dies, 129 individuals are reported to be admitted to the emergency room, and 13 are reported to be hospitalised.[2] Huge proportion of people who survive following a major injury may suffer from various degree of temporary or permanent disability. Apart from adverse physical consequences, these people often face severe economic and psycho-social consequences. These injuries predominantly affect the economically productive population and causes enormous burden on the health care system and on society.[3]

According to the World Health Organization statistics released in 2018, injuries result in multiple losses to the economy at individual, family and country level. Apart from the direct costs incurred during treatment and hospitalisation, the indirect costs due to loss of productivity is enormous. Accidents are reported to result in up to 3% loss of the country’s Gross Domestic Product.[1]

Injuries are more common in young age group and hence, it can be considered as a major cause for loss of potential years of the life of an individual. Haemorrhage is one of the trauma-related preventable causes of mortality. Injuries to the abdominal viscera, which are a major source of haemorrhage, present to us with few or no symptoms, making their assessment and management very difficult.[4, 5]

Even in cases of mortality in blunt abdominal trauma, there might be no external signs of trauma.[6] Furthermore, the diagnostic accuracy of physical examination in abdominal visceral injury is low. The associated injuries to the central nervous system pose additional difficulties in the diagnosis of abdominal trauma due to altered level of consciousness.[7] The cases without physical signs of abdominal pain may also harbour occult injuries. This often leads to missed diagnosis, especially in a resource limited setting where there is poor availability of necessary investigations and a huge reliance on clinical examination. This has been reported as a major contributing factor to preventable mortality among people affected by trauma.[8]

There are two types of abdominal trauma, namely, blunt and penetrating trauma. Penetrating trauma mostly affects the liver, small intestine and colon. In blunt abdominal trauma, the traumatic effects are transferred through the abdominal wall to the internal organs, and hence, the organs most affected are the spleen and the liver. Other organs which are affected include the bladder, rectum, along with structures like mesentery, diaphragm and major blood vessels. External compression, deceleration and crushing injuries are the major causative forces in blunt abdominal trauma. In case of blunt trauma, abdominal visceral injury contributes to as much as 13% of the cases.[9]

Road accidents cause for about 75% of blunt trauma cases. Assaults & fall contribute to about 15% and 10% of the cases respectively. Studies have indicated that the incidence of blunt abdominal trauma has been increasing in the past decade. However, the mortality has remained steady or in other situations has declined. Patients with multiple injuries must be evaluated thoroughly for abdominal injuries by imaging because most of the injuries affecting abdominal viscera are treatable and a great proportion of the patients can recover completely.[8]

Computed tomography has significantly enhanced the current knowledge regarding abdominal trauma.[10] Accurate diagnosis of blunt abdominal trauma has now been made possible with advances in CT imaging techniques.[4,11] CT has also been useful in the evaluation of multiple injuries and to base the clinical decisions depending on the severity of injuries.

Inferior Vena Cava is an important diagnostic tool for the evaluation of patients with blunt abdominal trauma. The diameter of IVC changes in response to intravascular volume in the patients. Hence, the IVC diameter can be used as a predictor of blood loss and hypovolemia in patients with blunt abdominal trauma. Assessment of Inferior Vena Cava can be done using either Ultrasonography or CT imaging. Ultrasound imaging is difficult since the presence of bowel gas, inter-observer variability and the presence of subcutaneous emphysema might complicate the visualisation of IVC to assess the presence of hypovolemia. Hence, CT imaging has been found to be superior to USG in assessing the IVC diameter in patients with blunt trauma.

Need of the study:

Previous studies evaluating the predictive value of IVC diameter to assess hypoperfusion in blunt abdominal injury have been conducted in Western Countries. Since the burden of blunt abdominal trauma is more in Low- and Middle-income countries such as India, it calls for the development of various rapid diagnostic modalities to aid in early diagnosis, for faster initiation of treatment and for reducing the preventable mortality. There are very limited number of studies conducted on the predictive utility of Flat IVC in the Indian population. Hence the quality of currently available evidence is insufficient to make strong clinical practice recommendations. There is certainly a strong need for a greater number of studies on the Indian subjects, to enhance the quality of available evidence. This in turn may have a huge impact on timely diagnosis of abdominal injuries, their effective management and may help in preventing both mortality and morbidity. Hence the current study was conducted to assess the independent predictive value of IVC diameter in assessment of hypotension among those with blunt abdominal trauma.

AIM

1. To assess the diameter of IVC on axial section of CT scan of abdomen as the predictor of hypotension in blunt abdominal trauma.

OBJECTIVES

1. To obtain a contrast-enhanced CT scan of the abdomen in patients who presented with a history of blunt abdominal trauma.
2. To assess the diameter of IVC in the venous phase as a predictor of hypotension.

REVIEW OF LITERATURE

GLOBAL BURDEN OF BLUNT ABDOMINAL TRAUMA:

Ong et al[11] (1994) found that 79% of the abdominal trauma cases in Singapore were due to blunt trauma.

Watts et al[12] (2003), aimed to define the prevalence of blunt HVI (Hollow Viscus Injury) along with associated morbidity and mortality rates. They conducted an analysis of the data on blunt small bowel trauma admissions to multiple (95) trauma care institutions in the Eastern part of the USA, for a study duration of 2 years. They found that, out of all the trauma patients, nearly 83% had blunt abdominal injury. Hollow viscus injury accounted for 1.15% cases, and < 0.3% of cases had perforating injury to the small intestine. It was found that the rates of mortality and morbidity were much higher among patients with HVI compared to those without HVI.

Cooper et al[13] (2005), used data from a trauma database in Scotland to do a retrospective analysis to determine the occurrence of abdominal trauma in cases with chest and/or pelvic trauma. The study utilized data over a period of 5 years. Concomitant abdominal injuries were found in 14% of the cases with chest trauma and no pelvic trauma. In comparison, 8% of patients with only pelvic trauma had abdominal trauma also. In polytrauma cases, with both chest and pelvic injuries, 47% had injuries to the abdomen. A significant increase in the occurrence of abdominal trauma was noticed with an increase in severity of the chest and pelvic trauma.

Salimi et al[14] (2009), studied the trauma patients admitted to the emergency department in hospitals of Tehran, Iran, for a period of one year. Out of the total, 2.8% presented with abdominal trauma. The majority of the patients were males in their 20s and 30s. Blunt abdominal trauma cases were found to be more prevalent than penetrating trauma cases. The mortality rate was also found to be higher in blunt trauma cases.

Costa et al[15] (2010), recognised that 7 to 10% of all trauma cases had abdominal trauma. Polytrauma is often seen with orthopaedic injuries, thoracic injuries and CNS injuries. They conducted a study using a multidisciplinary trauma registry in Italy.

Gad et al[16] (2012), studied the prevalence and the subtype of abdominal injuries in Egypt. Out of all the trauma patients admitted over a period of around 5 years, nearly 83% of the patients had suffered from abdominal trauma. Blunt force trauma was found to be the cause in 70% of abdominal trauma cases.

Hemmati et al[17] (2013), evaluated chest and abdominal trauma patients in a teaching hospital in Tehran, Iran. The majority of patients with abdominal injuries had blunt type of trauma (72.1%), and the mortality rate due to the same was 4.3%.

Arumugam et al[18] (2015), conducted a retrospective analysis of the descriptive data regarding patients admitted with abdominal trauma in a trauma centre in Qatar over a 4-year period. Abdominal trauma accounted for 15% of all trauma patients. Young males constituted the overwhelming majority.

Nishijima et al[8](2012), aimed to characterise intra-abdominal injuries in cases with blunt abdominal trauma (BAT). A systematic search of studies examining intra-abdominal injuries over a period of several decades was conducted. The search results showed an incidence of intra-abdominal injuries to be 13% in adult blunt abdominal trauma patients admitted to the emergency department. There was statistically significant heterogeneity in this finding, although the confidence intervals were notably clinically narrow.

BURDEN IN INDIA:

Ghosh et al[19] (2011), mentioned the relative lack of epidemiological data regarding abdominal trauma. A prospective observational study was conducted among the abdominal trauma patients admitted to a hospital in Kolkata, India. It was found that young males were the major sufferers of the disease condition. Nearly three-fourths of the subjects had blunt type of trauma. The virtual absence of pre-hospital care in the region and the lack of a uniform management protocol were found to be the major issues.

Jha K et al[20] (2014), studied hollow viscus injury in blunt abdominal trauma patients admitted to a hospital in Ranchi, India, over a period of 4.5 years. More than 87% of total cases were found to be men with an average age of 29 years. They concluded that early recognition of intestinal injuries in BAT is critical, although it may be difficult.

Mehta et al[21] (2014), noted that trauma though a major cause of mortality and morbidity is a neglected disease of modern society. The authors conducted a retrospective analysis on BAT patients in a hospital in Bangalore, India, over a period of 18 months. The abdomen was frequently affected, and blunt abdominal trauma constituted 85% of all abdominal traumas. Predominantly young males were affected.

Shubhendu et al[22] (2016), stated that the abdominal cavity is an important site for trauma in road accidents due to the presence of multiple vital organs such as liver, spleen, kidney, stomach, intestines, etc. The authors conducted an analysis of BAT based on autopsy findings in a hospital in Ranchi, India. They found that BAT was commonly associated with thoracic injury (67% of cases) and with head trauma (54%). The most frequent cause of death was neurogenic shock and haemorrhage. Nearly half the patients died within 2 hours of the accident.

Krishnappa et al[23] (2017), analysed abdominal trauma cases in the emergency department of a hospital in rural Karnataka, over a period of 4 months. Among all trauma cases, the incidence of abdominal trauma was found to be 52% and among these two-third cases had blunt abdominal trauma. Nearly three-fourths of the patients were men. Accompanying injuries such as chest trauma, head and neck injuries were seen in around 56% of cases of abdominal trauma and significantly more common among blunt trauma cases.

Malhotra et al[24] (2017), recognised Blunt Abdominal Trauma (BAT) as the third most common type of trauma worldwide and an important cause of mortality and morbidity in India. In their study among patients with BAT conducted in Himachal Pradesh, they concluded that BAT especially affects the 11-40 years age group. Males were affected more compared to females.

Solanki et al[25] (2018), conducted a study on BAT patients admitted to a tertiary care hospital in Gujarat, India, over a period of 2 years. Majority of the patients were found to be young males (M:F ratio of 2.8:1) in the age group of 11 to 30 years. Late presentation to the healthcare facility led to death in 67% of the patients.

COMMON ETIOLOGIES OF BLUNT ABDOMINAL TRAUMA:

Munns et al[26] (1995), analysed data of the patients who had blunt trauma to the small intestine and/or to the colon over a period of 11 years in two hospitals in Australia. It was observed that nearly 85% of the cases were injured due to vehicular accidents.

Rifat et al[27] (2003), noted that abdominal injuries are not common in sports. But they stressed on the fact that the physician should recognize the warning signs of dangerous trauma to the spleen, liver or hollow viscus organs.

Barrett et al[28] (2012), recognized that athletic events have the potential to cause trauma to the abdomen. When an athlete is hit in the stomach with shoulder, helmet, or by falling onto hard objects such as a ball it causes a blow to the solar plexus which is the most common distress injury in athletes. Organ damage is specifically dangerous due to the potential of internal bleeding or organ failure.

Naik et al[29] (2013), studied victims of blunt abdominal injuries over one year in a hospital in Telangana. Road accidents were found to be the most common form of injury (63%), followed by accidental fall from height (15%). These included fall from trees, rooftops, fall in elderly and fall under the influence of alcohol. Industrial accidents were responsible in 4% of cases and assault in 9% cases.

Reddy B et al[30] (2014), aimed to analyse the epidemiology and pattern of BAT in road traffic accidents (RTAs) in Bangalore, India. It was found that 54% of blunt abdominal trauma were caused due to road accidents involving a heavy vehicle, one-fourth of cases involving a light motor vehicle, 12% of cases involving two-wheeler and remaining 10% were due to unknown ‘hit and run’ cases.

Jhak et al[20] (2014), found that in the majority of cases, the cause of hollow viscus injury in abdominal blunt trauma was road traffic accidents (57%). Fall from height was another important cause, contributing to more than one-third of the cases (36%). Trauma due to assault was less common at around 6%.

Arumugam et al[18] (2015), found injuries due to road traffic accidents (RTA), seen in 61% of cases, as the most frequent cause of BAT in their study on patients admitted to a hospital in Qatar. The relatively less important causes were fall from height (25%) and fall of heavy objects (7%).

Pimentel et al[31] (2015), conducted a retrospective analysis of patients suffering from BAT who required laparotomy on an emergency basis over a period of 23 months in a hospital in Brazil. The major mechanism of trauma was automobile accident (as seen in 85% of the cases). Among those who were injured due to such accidents, 63% were healed while the remaining cases died. The other causes of BAT were direct abdominal trauma (8.2%) and fall (7%).

A prospective study was conducted by Sharma et al[32] (2017), on BAT patients admitted to a hospital in Andhra Pradesh over a period of 2 years. The most frequent cause of injury was found to be road traffic accidents (28%). Being hit by objects and fall from height were both equally common at 26% each. Assault was the mechanism of injury in 20% of the cases.

In a study by Amuthan et al[33] (2017), patients with a history of blunt abdominal trauma admitted to a teaching hospital in Tamil Nadu were included in the sample and patients with gunshot and penetrating injuries were excluded. In the majority of the cases (two-third cases), the cause was found to be road traffic accident followed by fall from height (22%) while minor causes included being hit by a blunt object (6%) and assault (4%).

Agarwal et al[34] (2017), assessed patients admitted with blunt abdominal trauma over a period of one year in a hospital in Rajasthan. The predominant mode of injury encountered was motor vehicle accidents as seen in nearly two-thirds of the cases.

Choua et al[35] (2017), reviewed data from medical records of patients admitted with blunt abdominal trauma over a period of 5 years in a tertiary care hospital. The major etiological mode identified was road traffic accidents (as seen in more than 61% of the cases). Less common causes were assaults (8.2%) and wall collapses (14.3%). Fall from a height constituted 6.3% of the cases.

O'Rourke et al[9] (2019), noted that most of the blunt abdominal trauma cases in the USA were due to road traffic accidents involving motor vehicles. Less common causes included fall from height, sports injuries, industrial accidents and bicycle injuries.

Shashikumar et al[36] (2018), studied blunt abdominal solid organ injuries admitted in a medical college in Karnataka over a period of one year. They found that the most significant mode of injury in these cases was road traffic accident (53% of the cases). The second important cause was fall from height (31%). Assault was seen in 15.5% of the cases.

Kumar et al[37] (2018), analysed data on internal or external abdominal injuries due to blunt trauma gathered from dead bodies in a medical institute in Uttar Pradesh. The type of vehicle most frequently involved in the causation of such trauma were two-wheelers (70%). Pedestrian and three-wheeler accidents was responsible for 11.3% and 12% respectively. Four-wheelers were low on the list of the type of vehicles responsible at 6.7%.

Umare et al[38] (2018), conducted a prospective study of BAT patients admitted to a hospital. It was concluded in the study that road traffic accidents were the first common mode of injury observed in 50% of cases, followed by fall from height observed in 28% of cases and lastly assault was observed in 20% of the cases.

Trehan et al[39] (2018), retrospectively studied data on patients suffering from BAT collected over a period of 5 years in India. Most commonly, the cause of abdominal trauma was road traffic accidents (68%). Fall from height (15%) and assault (13.4%) were other important causes. Strike by a heavy object was relatively uncommon at 3.5%.

Adam et al[40] (2018), observed that abdominal injuries were relatively rare in sports and were mostly caused in sports involving contact and collision. Abdominal injuries in sports are the result of high or low energy blunt trauma and are caused in athletes, mainly due to non-usage of abdominal protective equipment. Side-line management of abdominal trauma in sports is challenging because even trauma which appears insignificant initially may lead to serious life-threatening injuries. Splenic trauma accounts for a quarter of all BATs. Liver injuries are seen in 15-20% of all BAT cases. But they cause up to half of all BAT-related mortality.

Legome et al[41] (2019), stated that BAT is caused in the general public, mainly due to vehicular trauma. In 50 to 75% of cases, the cause was found to be road accidents involving a vehicular collision or pedestrian- vehicular collision. Less important aetiologies were falls and accidents caused in industries or in recreational activities. Relatively insignificant causes were iatrogenic CPR-related injury, manual thrusts which were done for clearing the airway, and even the Heimlich manoeuvre.

RISK OF INJURY TO VISCERA AND VASCULAR STRUCTURES:

Miller et al[42] (2002), analysed retrospective data from the records of hemodynamically stable patients with SOI (Solid-organ Injury) in the form of injury to liver, spleen or both due to BAT in a trauma centre over a period of 3 years. The most commonly injured organs were spleen alone (43%), liver alone (42.1%) and liver and spleen together (15%). It was found that bowel injury and pancreatic injury were statistically more common in the group suffering from liver injury alone. Such a statistically significant difference was not seen for bladder injury.

Velmahos et al[43] (2003), prospectively observed BAT patients in a teaching hospital. During the period of the study, half of the patients had an injury to the spleen while nearly half (48%) had an injury to the liver. Renal injury (19%), two-organ injury (11%) and three-organ injury (7%) were the other most common findings in patients.

Kokabi et al[44] (2014), aimed to present a multidisciplinary management protocol for common intra-abdominal solid organ injuries. The authors noted that splenic and hepatic injuries are the most frequently seen solid organ injuries in patients with BAT. Renal and pancreatic injury are relatively less common. They mention that splenic injuries accounts for 49% of all BAT injuries, while the liver injury is seen in 1-8%. Although hepatic injuries are less common, they are the most prominent cause of death due to BAT. Kidneys are damaged in 1 to 5% of all BAT patients while the pancreatic injury is seen in less than 2% of all BAT cases. Pancreatic injury is almost never seen alone and is most prevalent in younger people who have less retroperitoneal fat. Hilar and segmental vascular injury in the spleen with extravasation, injuries to the retro-hepatic inferior vena cava or major hepatic veins, damage to the main renal artery or vein with hemorrhage and general hemodynamic instability are major considerations in the management of BAT.

Kulkarni et al[45] (2015), conducted a prospective study of the cases of BAT admitted in a rural hospital in Maharashtra over a period of 2 years. Of all the BAT patients, around 42.65% had evidence of intra-abdominal injury or perforation. The most commonly injured hollow viscus organ was the small bowel, accounting for 13.8% of all internal abdominal injuries. The most commonly affected organ overall was the spleen, injuries to which were seen in 27.6% of the total. Mesenteric injuries were found in 17.2% of the cases. Less commonly affected organs were large bowel, stomach (6.9%), urinary bladder (6.9%), liver (6.9%), urethra (3.45%), pancreas (3.45%), and kidneys (3.45%).

Baghdanian et al[46] (2016), noted that assessment of the arterial supply of liver and spleen along with major upper abdominal vascular injuries up to the level of the superior mesenteric artery may be necessary in cases of BAT. Active haemorrhage, vascular tears, vessel dissections, pseudo-aneurysms, arteriovenous fistulas, intraluminal thrombosis and vessel contour abnormalities are some of the forms of vascular injury. The major sites of vascular injury included the aorta, that of the liver, spleen, kidneys and bowel and mesentery. Abdominal aortic injury is most dangerous, although rarer than injury to the thoracic aorta. The zone between the inferior aspect of the renal arteries and the aortic bifurcation is the most common site of injury. In the liver, portal vein and hepatic vein injuries both along with injuries to the hepatic arteries complicate the situation.

Kobayashi et al[47] (2016), states that abdominal vascular trauma, although lethal, is generally rare and is typically associated with penetrating trauma. The most commonly affected vessels are the aorta, superior mesenteric artery, iliac arteries, IVC, portal vein, and iliac veins.

Srivastava et al[48] (2017), studied patients admitted with BAT in a hospital in Uttar Pradesh over a period of 1 year. The frequent site of injury in patients of blunt abdominal trauma was found to be jejunum, followed by the ileum. Splenic and hepatic injuries were found to be next frequent sites in BAT. Less common injuries included renal injury, bladder injury and mesenteric tear.

El-Menyar et al[49] (2017), retrospectively analysed data on patients with solid organ injuries (SOIs) due to BAT over a period of 3 years. It was found that the most commonly damaged organs were the liver (45%), followed by the spleen (in 30% of cases) and the kidney (18%). One-fifth of the patients suffered from injuries to multiple solid organs, out of which 87% suffered from injury to two organs. Those with multiple SOIs were found to suffer more commonly from a head injury and more severe injuries in general.

Jain et al[50] (2017), studied cases with a history of either penetrating or blunt abdominal trauma admitted to a teaching hospital in Madhya Pradesh, India for a period of 18 months. All the patients were found to have hollow viscus injury, out of which injuries to the ileum and the jejunum were largely predominant. On ultrasonography, it was observed that the most frequently affected solid organs were spleen and liver.

Bansod et al[51] (2018), conducted a longitudinal study among cases of blunt abdominal injury over a period of 2 years. 40.6% of cases with BAT had features of SOI on ultrasonography. Isolated injuries to the spleen were present in 16.7% of cases with BAT history. 10.1% of BAT cases were established to have isolated liver injuries. 1.45% of the BAT cases presented with an isolated injury to the pancreas. Multiple SOIs were seen in 6.5% of patients with a history of BAT. Spleen and left kidney were affected in 8.33% of hemodynamically stable BAT patients while the proportion of cases with injury to both spleen and liver was also 8.33%. Those having an injury to both spleen and pancreas constituted only 2.1% of such cases.

Weale et al[52] (2018), reviewed the data collected on patients who were subjected to laparotomy for abdominal trauma for a period of 4 years in a hospital in South Africa. They found that 8.6% of all patients who underwent laparotomy had Intra-Abdominal Vascular Injuries (IAVI). Out of those having IAVIs, more than 89% had suffered from penetrating trauma in the form of gunshot wounds and stab wounds, and only 11% were victims of blunt trauma.

Legome et al[41] (2019), noted that the mechanisms of injury involved in blunt abdominal trauma are broadly of three types. The most important mechanism is rapid deceleration and the resultant shear forces which causes tearing of hollow, solid visceral organs and vessels, typically at points of their attachment. Commonly affected areas are the liver, renal arteries and aorta. The second important mode involves crushing between the posterior vertebral column/thoracic cage and the anterior abdominal wall. Solid organs such as spleen, kidneys and liver are particularly under threat. Lastly, external compression from direct blows or against a fixed object such as the spinal column or a belt is important. Typically, hollow viscus organs are affected. Overall liver, spleen, small intestines and large intestines are affected most frequently in that order.

Incidence of hypovolemic shock and contribution to mortality:

Morales et al[53] (2004), studied intra-abdominal infections in abdominal trauma patients. They concluded that the amount of third-space fluid was associated with the severity and duration of hypovolemic shock leading to hypoperfusion and hypoxia, which was found to be linked with increased risk for infection. Another separate risk factor recognized for infections was blood transfusion.

Wang J et al[54] (2013), observed Hypovolemic Shock Complex (HSC) only in 5% of BAT patients. But there is an association between such HSC findings and poorer patient's outcome, typically with the mortality which increases up to 70%. The main causes of hypovolemic shock were noted as major vessel rupture, arterial lacerations and solid organ injuries. They suggest that a clear distinction should be drawn between haemorrhagic shock and blunt organ injury as it is typically the organ injury which requires surgical action.

Shalhub et al[55] (2014), studied blunt abdominal aortic injuries in multiple centres over a period of 15 years. The proportion of blunt trauma patients who suffered from blunt abdominal aortic injury (BAAI) was 0.03%. Hypotension was identified in 47% of the cases. The overall mortality rate was 39%. More than two-thirds of the deaths occurred in the first 24 hours, primarily due to haemorrhage or cardiac arrest. Zone II aortic ruptures were associated with the highest death rates of 92%.

Wang SY et al[56] (2014), analysed a series of patients who suffered from BAT and managed with Damage Control Laparotomy (DCL) in a hospital over a period of more than 10 years. All these patients underwent DCL because of haemorrhagic shock. The authors found that 61.5% of the patients died. They concluded that DCL can be a life-saving procedure in critically exsanguinated patients.

Mehta et al[21] (2014), made a note that around 10% of patients with BAT develop refractory hypovolemic shock due to persistent blood loss in the face of aggressive fluid resuscitation, indicating the need for urgent laparotomy. In their study, they observed that 34% of the patients were in hypovolemic shock on presentation. The death occurred in 4% of cases studied and the most common cause was irreversible shock. The deaths due to post-operative hypovolemic shock occurred in cases of major splenic injury and small bowel trauma.

Pimentel et al[31] (2015), mentioned that one of the risk factors for mortality among the cases with abdominal trauma is shock upon admission. Haemorrhagic shock without apparent cause was the most frequently observed clinical feature in patients in whom abdominal trauma had been suspected. The leading cause of mortality in such patients has been identified as hypovolemic shock.

In the study by Arumugam et al[18] (2015), 6% of the patients died within the first 24 hours of admission to the hospital. Among these cases, unresponsive shock due to exsanguinating injuries was a common cause of death. 2.3% of the cases died after the first 24 hours of admission. Among those, the haemorrhagic shock was less important, contributing to 8.3% of the deaths.

Boese et al[57] (2015), aimed to identify factors affecting prognosis and failure of Non-Operative Management (NOM) of blunt hepatic injuries. They conducted a systematic review and found that the blood pressure, fluid resuscitation and blood transfusion were some of the important statistically significant prognostic factors. They concluded that sufferers of blunt liver injuries who present with clinical signs of shock are at an increased risk of failure of Non-Operative Management (NOM).

Sharma et al[32] (2016), found that shock was the second most common presentation, seen in 15% of cases of BAT. One patient who was initially managed conservatively had to be taken in for surgery for development of shock due to bleeding from grade II splenic injury. The authors noted that BAT poses a dilemma from the diagnostic and therapeutic point of view as patients present with a wide variety of symptoms ranging from no findings to refractory shock.

Shubhendu et al[22] (2016), identified haemorrhagic shock as the major cause of death in cases with BAT, contributing alone to about 47% of the cases and contributing together with neurogenic shock to 43.6% of the cases. Out of those who died due to haemorrhagic shock alone, 39.5% died in the first 24 hours. When both neurogenic and haemorrhagic shock co-existed, death happened in the first 2 hours in 39.5% of the cases. The authors also observed that shock was the main mechanism of death in the first 24 hours after trauma, while sepsis was the main cause in those who survived beyond 24 hours.

Vadamalai et al[58] (2016), conducted an analysis of BAT cases admitted to a hospital in Tamil Nadu over a period of one year. It was observed that 20.8% of the cases presented with shock, out of which 45.5% had an injury to the spleen, 27.3% had a hepatic injury, 18.2% had perforation of the small bowel, and 9.1% had large bowel perforation. Hypovolemia was the cause of death in only 11%, while septicaemia was the most common cause of death.

Sheshe et al[59](2017), studied case records of patients with abdominal trauma in a hospital in Nigeria over a period of 2 years. Cases of both penetrating and blunt trauma were taken into consideration. 29% of the patients were established to have hypotension, tachycardia, low pulse pressure, and shock index >1. The shock was identified as one of the main factors associated with mortality, along with gunshot injuries, multiple injuries, sepsis and lack of facilities.

Ruscelli et al[60] (2017), aimed to describe over his 10 years worth experience about management of blunt abdominal trauma in a single trauma hospital in Italy. The hemodynamic stability of the patients was assessed, and the patients were categorised into groups. 4.5% of mortality was found in patients who were stable hemodynamically and did not undergo surgery. Patients in the unstable group, who underwent surgery suffered from a mortality rate of 15.3%. The relative risk of death among the non-operative group over the surgery group was an odds ratio of 3.41 with 95% confidence intervals; it was also observed that patients above 40 years of age had more statistically significant mortality.

Jabbour et al[61] (2017), noted that massive haemorrhage following blunt abdominal trauma is mainly caused due to injury to the spleen. A retrospective study was conducted on patients with injured spleen following blunt trauma in a hospital in Qatar. Blunt Splenic Injury (BSI) accounted for 22% of all annual BAT admissions. The systolic blood pressure was less than 90 mm Hg in more proportion of patients with Grade IV splenic injury. No statistically significant data for the difference in this proportion over the grades of splenic injury was observed (p=0.11). The overall mortality rate was 7.9%. Among those with grade V splenic injury who died, 67% died due to irreversible haemorrhage and shock within one day. Overall, the most common cause of death was associated with severe Traumatic Brain Injury (TBI).

Prichayudh et al[62] (2019), analysed data regarding Abdominal Vascular Injuries (AVI) in a hospital in Thailand over a period of 10 years. Both blunt and penetrating injuries were included. AVI patients were equally distributed between these types of injuries. More than three-fourths of the cases were in shock on arrival to the trauma centre. Higher Injury Severity Scores (ISS) were found in abdominal vascular injuries. Damage control operative procedures were done more frequently in the blunt trauma cases (89.3% of the cases) compared to the 74.1% in penetrating injury cases. Mortality rates were also higher in blunt injuries at 50% compared to 30% in penetrating trauma. However, this difference was not found to have considerable statistical significance ($p=0.205$).

DIAGNOSIS OF HYPOVOLEMIC SHOCK:

History and physical examination often provide clues to the diagnosis of shock. Hypovolemic shock due to haemorrhage often presents with a history of trauma. The symptoms of hypovolemic shock are due to low blood volume, altered acid-base balance and tissue hypo-perfusion.

The patients might present with symptoms of increased thirst, postural hypotension and muscle cramps. If mesenteric ischemia occurs, as in cases of blunt abdominal trauma, abdominal cramps can occur. On examination, dry mucus membranes, cold clammy skin and loss of skin turgor were present.[63]

Shock index is obtained by dividing the heart rate by systolic BP. A shock index of more than or equal to 0.6 is clinical shock. It has a direct correlation with the degree of hypovolemia and thus can identify the high-risk patients. A shock index of > or =0.6 and less than 1.0 is a mild shock, SI > or =1 to less than 1.4 is moderate shock and shock index > or = to 1.4 is severe shock.[64]

Based on the degree of blood loss in trauma, the patients are classified into the following classes:[65]

Class 1 Shock: Blood loss amounts to almost 15% of the total volume of blood. There is no significant change in vitals such as HR, BP and pulse pressure.

Class 2 Shock: Blood loss amounts to 15% to 30% of the total blood volume. Tachycardia can occur. Pulse pressure starts narrowing down. There might be no change in the systolic BP other than a mild decrease.

Class 3 Shock: Blood loss amounts to 30 to 40% of total blood volume. A significant lowering of BP and altered sensorium can occur. Tachycardia and tachypnoea are present. There is reduced urinary output and prolonged capillary refill time.

Class 4 Shock: The total blood loss exceeds 40% of total blood volume. Tachycardia and altered sensorium are marked. Hypotension, oliguria or anuria and delayed capillary refill are also present.

With regards to laboratory parameters, reduction in haemoglobin can occur in trauma patients with marked blood loss. However, haemoconcentration might result in a false elevation of haemoglobin values.

The frequently used method to assess the presence of hypovolemia is central venous pressure. But it has been recently found to be inadequate for diagnosing hypovolemia. Compliance of the chest wall, presence of right heart failure are some of the confounding factors that may affect the accuracy of central venous pressure in assessing hypovolemia. Measurement of pulse pressure to assess the fluid volume is effective only among patients who are spontaneously breathing. This is also not accurate in cases with increased respiratory rates, reduced compliance of chest wall and with right heart failure.[66, 67]

Due to non-specific symptoms and the inadequate diagnostics for identifying hypovolemia and haemorrhagic shock, additional parameters are required with improved sensitivity and specificity to diagnose hypovolemic shock.

Physiological changes in major vessels:

Hypotension and hypovolemia due to blood loss in blunt abdominal trauma result in physiological changes occurring in the major blood vessels. Imaging procedures such as CT scan and ultrasound were usually used to evaluate anatomical and pathological defects. However, in recent times, imaging has also been used to assess various physiological changes. Imaging techniques are non-invasive, and hence they are of great utility in the rapid assessment of fluid loss among those with blunt abdominal trauma.

Physiology of inferior vena cava changes:

Inferior vena cava is a compliant major blood vessel which alters its diameter in relation to the intravascular volume. The diameter of the inferior vena cava varies from individual to individual. However, it has been reported that the maximal diameter of the inferior vena cava is lesser among those with hypovolemic shock.[68]

The collapsibility index of the inferior vena cava is also used to measure the volume status along with dimensions. The collapsibility index of the inferior vena cava is also termed as the caval index.[69]It is the difference between the highest diameter of the IVC during expiration and the lowest diameter of the IVC during inspiration which is divided by the maximum diameter of the IVC. When the caval index is more than 50%, it indicates the presence of hypovolemia. The predictive value is higher when the caval index is combined with a small diameter of the IVC. [69, 70]

Various studies have been conducted with regards to changes in major blood vessels during blood loss.

Barbier et al[71] (2004), conducted a study on the predictive value of inferior vena caval diameter in fluid responsiveness among those who are in hypotensive shock. They measured the inferior vena cava diameter at the end of inspiration and expiration. The percentage of the difference between the highest and lowest diameter of IVC divided by the lowest diameter of the IVC was used to calculate the distensibility index. Patients were classified based on response to fluid therapy into responders and non-responders. It was reported that, when a threshold of 18% was used as a cut-off to classify the distensibility index, there was a 90% sensitivity and 90% specificity in predicting the responsiveness to fluid therapy. Hence the authors concluded that IVC diameter could be accurately used to predict the responsiveness to fluid therapy among patients in shock.

Feissel et al[72] (2004), conducted a study on the utility of IVC diameter in developing a guide to fluid therapy. It was reported that after administering a standardised volume load, there was a 5.2% to 5.8% change in IVC diameter. The baseline respiratory variation in IVC diameter was significantly higher among those who responded to fluid therapy, compared to non-responders. A cut-off value of 12% variation in IVC diameter accurately identified responders and non-responders.

Yanagawa et al[73] (2005), conducted a study on the association between the IVC diameter and hypovolemic shock. They measured the IVC diameter among trauma patients with and without shock both during arrival and on day 5. It was reported that patients with shock had a significantly lesser IVC diameter on an average compared to the controls. These patients in shock had the IVC diameter of 9 mm or less, in addition to significantly lower haemoglobin levels. There were no considerable changes in the IVC diameter among those without shock after 5 days following admission. However, among the trauma patients with shock, there was a considerable improvement in IVC diameter after 5 days following admission when the fluid replacement was performed. Hence the authors conclude that among the trauma patients with hypovolemia, there is a significant correlation between IVC diameter and fluid status.

Even minimal amount of blood loss results in quantifiable changes in IVC diameter. Lyon M et al[74](2005), conducted a study on the value of IVC diameter as a marker in predicting blood loss. They included 31 participants who were 49.5 years old on an average. Blood donation was used to study the effects of blood loss. The average IVC diameter during expiration was 17.4 mm before the participants donated blood. After donating blood, the IVC diameter decreased to 11.9 mm. The reduction in IVC diameter was 8.13 mm on an average after blood donation. There was a considerable reduction in IVC diameter at both inspiration and expiration after blood donation, which causes a blood loss of around 450 ml. Considerable correlation between IVC diameters at inspiration and expiration was observed. Hence, the authors suggest that measurement of IVC diameter could be used to reliably predict even a blood loss as less as 450 ml. Thus, measuring the IVC diameter could be used to evaluate trauma patients in whom volume depletion can occur as a result of blood loss.

Sefidbakht et al[75] (2004), studied the relationship between IVC diameter and shock among trauma patients. They included 88 patients in total, among those 11 had shock and 77 patients had no shock. The AP-diameter of the inferior vena cava was measured during inspiratory and expiratory phases. The collapsibility index of the IVC was measured. It was found that the trauma patients with shock had considerably lower IVC diameter at both inspiration and expiration compared to those without shock. The IVC diameter at expiration was inversely correlated with the risk of shock. The mean inferior vena cava collapsibility index was significantly greater among trauma patients with shock. Hence, the authors recommend measuring IVC diameter as an additional tool in the evaluation of trauma patients.

Murphy et al[76] (2009), conducted a study on the changes in IVC diameter caused by intravascular volume changes. They measured the diameter of the IVC at 1 cm as well as 5 cm below the level of the renal vein using CT among those with abdominal trauma. Measurements were done both at the time of admission as well as after fluid replacement. It was found that all the patients had a collapsed IVC with a diameter of less than 15 mm. A considerable increase in IVC diameter at the infrarenal segment was noticed after resuscitation with fluids. An increase from 6.9 mm to 15.7 mm was noticed in IVC diameter during follow up. The minor axis of the IVC underwent an 84% increase in volume due to 5 times expansion of minor axis size. In contrast, the major axis did not undergo much significant change with only 5% increase in volume. The left-anterior-oblique orientation of the IVC did not change after fluid resuscitation and at times, resulted in under-estimation of the size of the IVC.

Nguyen et al[77] (2014), studied the IVC diameter among trauma patients with occult shock. They included 264 patients with trauma, among whom 52 had a flat inferior vena cava which was measured using CT. It was observed that, among those with a flat IVC, the severity of injury, serum lactate levels and base deficit were significantly higher than among those who had a normal IVC diameter. Furthermore, the fluid requirement and the need for blood transfusion of those with flat IVC were also significantly more**.** The trauma patients with a flat IVC were at a 2.87 times greater risk of developing occult shock and 2.26 times higher risk of developing complications compared to those who had a normal IVC diameter. Hence, the authors recommend measuring IVC diameter to predict high-risk patients who might require greater fluid support in cases of trauma.

Gui et al[78] (2015), conducted a study on the relationship between patient characteristics along with fluid status and the IVC diameter. They assessed the influence on IVC by parameters such as age, gender, body surface area, BMI and history of hypertension. It was found that none of these variables were significant predictors of IVC diameter and its collapse. Hence, they concluded that the fluid status can be reliably predicted by the IVC diameter and is not affected by the prior patient characteristics.

HYPOVOLEMIA INDUCED CHANGES IN AORTA:

Prior studies have shown the presence of correlation between the diameter of aorta and the fluid status. Jonker et al[79] (2010), conducted a retrospective analysis on the relation between aortic diameter and hemodynamic instability among patients with abdominal trauma. They included 43 patients with an average age of 37 years. The average pulse rate in the study population was 122 beats per minute and the mean blood pressure was 103/63 mm Hg. It was found that the average diameter of the aorta among the hemodynamically unstable patients was significantly lower compared to those who were hemodynamically stable. The authors added that this could have potential implications in assessing the fluid status and deciding on the size of the endovascular graft to be used in injuries of the aorta.

To confirm the results of the retrospective study, Jonker et al[80] (2010), conducted an animal study regarding the effect of blood loss on aortic diameters in porcine models. A considerable reduction in aortic diameter at all levels was observed due to hypovolemia. The diameter of the ascending aorta recorded a 38 to 40% reduction in diameter after blood loss. The thoracic aorta recorded an average of 32% reduction in diameter. The abdominal aorta experienced a 28% reduction in diameter following blood loss and resultant hypovolemia. The original dimensions of the aorta were restored after fluid replacement. Hence, the authors recommend monitoring the aortic diameters in assessing blood loss status and as a guide to fluid replacement.

Bilgin et al[81] (2019), studied the changes in both IVC as well as the abdominal aortic diameter in response to fluid loss. They included healthy volunteers and assessed the effect of blood loss in the form of blood donation and response to fluid therapy with 500 ml of normal saline. A blood loss of 500 ml caused a significant change in parameters such as shock index, caval/aorta index as well as abdominal aortic diameter. Furthermore, these parameters were also normalised after fluid replacement. Hence the authors suggest that monitoring of parameters such as caval/aorta index, the diameter of abdominal aorta would be useful in early identification of blood loss.

AAST GRADINGOF ABDOMINAL ORGANS:[82]

Spleen injury scale (1994 revision)				
Grade*	**Injury type**	**Description of injury**	**ICD-9**	**AIS-90**
I	Hematoma	Subcapsular, <10% surface area	865-01	2
			865.11	
	Laceration	Capsular tear,	865.02	2
		<1cm parenchymal depth	865.12	2
II	Hematoma	Subcapsular, 10%-50% surface area	865.01	
		intraparenchymal, <5 cm in diameter	865.11	
				2
	Laceration	Capsular tear, 1-3cm parenchymal depth that does not	865.02	
		involve a trabecular vessel	865.12	
				3
III	Hematoma	Subcapsular, >50% surface area or expanding; ruptured		
		subcapsular or parenchymal hematoma; intraparenchymal		
		hematoma ≥ 5 cm or expanding		
	Laceration	>3 cm parenchymal depth or involving trabecular vessels	865.03	3
			865.13	
IV	Laceration	Laceration involving segmental or hilar vessels producing		

		major devascularization (>25% of spleen)		4
V	Laceration	Completely shattered spleen	865.04	5
	Vascular	Hilar vascular injury with devascularized spleen	865.14	5
*Advance one grade for multiple injuries up to grade III.				

Liver injury scale (1994 revision)[82]

Grade*	Type of Injury	Description of injury	ICD-9	AIS-90
I	Hematoma	Subcapsular, <10% surface area	864.01	2
			864.11	
	Laceration	Capsular tear, <1cm	864.02	2
		parenchymal depth	864.12	
II	Hematoma	Subcapsular, 10% to 50% surface area	864.01	2
		intraparenchymal<10 cm in diameter	864.11	
	Laceration	Capsular tear 1-3 cm parenchymal depth, <10 cm in length	864.03	2
			864.13	
III	Hematoma	Subcapsular, >50% surface area of ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma > 10 cm or expanding		3
	Laceration	>3 cm parenchymal depth	864.04	3
			864.14	
IV	Laceration	Parenchymal disruption involving 25% to 75% hepatic lobe or	864.04	4
		1-3 Couinaud's segments	864.14	
V	Laceration	Parenchymal disruption involving >75% of hepatic lobe or >3		5
		Couinaud's segments within a single lobe		
	Vascular	Juxtahepatic venous injuries; i.e., add in short cut retrohepatic vena		5
		cava/central major hepatic veins		
VI	Vascular	Hepatic avulsion		6
*Advance one grade for multiple injuries up to grade III				

Pancreas Injury Scale[83]

Grade*	Type of Injury	Description of Injury	ICD-9	AIS-90
I	Hematoma	Minor contusion without duct injury	863.81-863.84	2
	Laceration	Superficial laceration without duct injury		2
II	Hematoma	Major contusion without duct injury or tissue loss	863.81-863.84	2
	Laceration	Major laceration without duct injury or tissue loss		3
III	Laceration	Distal transection or parenchymal injury with duct injury	863.92/ 863.94	3
IV	Laceration	Proximal transection[a] or parenchymal injury involving ampulla	863.91	4
V	Laceration	Massive disruption of the pancreatic head	863.91	5
*Advance one grade for multiple injuries up to grade III. *863.51,863.91 - head; 863.99,862.92-body;863.83,863.93-tail. [a]Proximal pancreas is to the patients' right of the superior mesenteric vein.				

Kidney injury scale:[84]

Grade*	Type of injury	Description of injury	ICD-9	AIS-90
I	Contusion	Microscopic or gross haematuria, urologic studies normal	866.01	2
	Hematoma	Subcapsular, nonexpanding without parenchymal laceration	866.11	2
II	Hematoma	Nonexpanding perirenal hematoma confined to renal	866.01	2
		Retroperitoneum	866.11	
	Laceration	<1.0 cm parenchymal depth of renal cortex without urinary	866.02	2
		Extravasation	866.12	
III	Laceration	>1.0 cm parenchymal depth of renal cortex without collecting system rupture or urinary extravasation	866.02	3
	Laceration	Parenchymal laceration extending through renal cortex,	866.12	4
IV		medulla, and collecting system		
	Vascular	Main renal artery or vein injury with contained haemorrhage		4
V	Laceration	Completely shattered kidney	866.03	5
	Vascular	Avulsion of renal hilum which devascularizes kidney	866.13	5

*Advance one grade for bilateral injuries up to grade III

ROLE OF CT IMAGING:

Abdominal CT is an important diagnostic tool, which can be used for BAT patients. In particular, CT imaging is especially helpful in the early diagnosis of solid organ injuries and injury to the vascular structures which are known to cause an increased risk of complications and mortality.[85] CT imaging is superior to other modalities due to its increased accuracy and patient safety profile. The various CT findings in blunt abdominal injuries are as follows:

Hemoperitoneum and free fluid in peritoneum:

Hemoperitoneum is more commonly found in association with injuries occurring to the solid as well as hollow abdominal viscera. The occurrence of free fluid in the pelvis is common in females during their menstrual cycle. However, among males, the occurrence of free fluid in peritoneum without any injury to viscera necessitates additional diagnosis.[86] In trauma cases, patients may or may not have free fluid on USG, however if it is detected then, a further CT scan should be done to rule out the presence of hemoperitoneum.[87]

Splenic injuries:

The spleen is commonly injured among those with blunt abdominal trauma. Since the spleen is involved in the body's immune function, the aim is to preserve the spleen following blunt abdominal trauma by avoiding splenectomy.[88] A CT based scale was developed by the American Association for the Surgery of Trauma (AAST) for splenic injuries, thus emphasising the importance of CT imaging in blunt abdominal trauma.[89]

Hepatic injuries:

Liver is also one of the frequently injured organs in blunt abdominal trauma, similar to the spleen. A CT based injury scale has been developed in the grading of liver injuries by AAST. Parameters such as the size, site of hepatic hematomas and hepatic lacerations are considered in grading hepatic injuries.[90-92] Since the advent of non-surgical management of liver injuries, the focus has now shifted from early to delayed complications such as abscess formation and delayed haemorrhage. These injuries are associated with leakage of bile into the adjacent structures.[93]

Bowel and mesenteric injuries:

5% of BAT patients have bowel and mesenteric injuries. But it is essential to diagnose bowel injuries using CT at the earliest due to the increased risk of mortality from peritonitis or septicemia.[94] Among the bowel injuries, the most commonly affected organ is the small bowel followed by the stomach and the colon. The CT findings in bowel injuries include pneumoperitoneum, hemoperitoneum, focal bowel wall thickening and wall transection. Injuries to the mesenteric vascular structures and resultant larger hematomas require urgent intervention due to the increased mortality due to bowel ischemia.[95]

Pancreatic and duodenal injuries:

Pancreatic and duodenal injuries mostly involve associated injuries to the left hepatic lobe or the spleen in addition. Diagnosing such injuries using CT is often challenging. There might be no CT findings in the injured pancreas for up to 12 hours after abdominal trauma. Pancreatic injury is inferred through signs such as fluid in the plane between the pancreas and splenic vein or in peri-pancreatic adipose tissue. Neck and body are the sites involved in pancreatic injuries. CT is useful in diagnosing additional duodenal injuries as well.[96, 97]

CT hypoperfusion complex:

CT is of great utility for assessing the hemodynamic status of those with blunt abdominal trauma. It enables the detection of hypovolemia which persists despite fluid management. The collective findings in CT, which include a flat IVC, reduced the diameter of aorta and diffusely thickened small bowel, pancreatic oedema together are termed as CT hypoperfusion complex.[98, 99]

Urinary tract and adrenal injuries:

Clinically, the presence of injury to the urinary tract can be assessed by a history of gross haematuria. Renal trauma has been classified by the American Association for the Surgery of Trauma (AAST) as per the size of the lacerations and hematomas along with their locations. In cases of pelvic fractures, bladder rupture can occur. In such cases, CT cystography is useful to rule out bladder injuries. In around 2% of the patients with blunt trauma, the adrenals are injured. If both adrenals are involved, adrenal insufficiency can occur.[100, 101]

Diaphragmatic injuries:

Injury to the diaphragm may cause an unexpected increase in intra-abdominal pressure. Herniation of the abdominal viscera into the thorax might result in their ischemia. CT findings in diaphragmatic injuries include loss of continuity, herniation of viscera and a waist-like constriction where the herniated viscera protrude from the abdomen through a dent in the diaphragm.[102]

Injuries to the major vascular structures:

Rapid blood loss is the reason for the association of high mortality with aortic injuries and injuries to other blood vessels. Diagnosis needs to be made early for timely intervention. Aortic transection is suspected if a large hematoma is present or if there is active extravasation of blood. Retroperitoneal blood loss associated with injuries such as pelvic fractures can also be accurately diagnosed using CT.[103, 104]

Various CT imaging findings of inferior vena cava are reported in blunt abdominal injuries. Some of them are as follows:

1. SLIT LIKE IVC/FLAT IVC:

The flat IVC sign or the collapsed inferior vena cava indicates the presence of hypovolemia and shock among patients with blunt abdominal trauma. This flat IVC occurs at multiple levels when imaging is done amongst the trauma patients. In contrast, this variation is absent at all levels in the case of normal transient fluctuations in the diameter of IVC due to respiratory changes or due to variations in intra-abdominal pressure.

Jhonson JJ et al[105], used a simple univariate logistic regression to find the association between IVC ratio and in-hospital mortality. This analysis had found a marginal association (p=0.0063). But the use of IVC ratio for the diagnostic or prognostic purpose required threshold or cut off values. Hence the authors determined the “cut off” value using area under the curve (AUC) of a receiver operating characteristic plot. Patients with IVC ratio falling above the cut-off value were considered to have a FIVC (exposed), and those with IVC ratio falling below the cut-off value were considered to have a non- FIVC (NFIVC; unexposed). The accuracy of the cut off values was based on the sensitivity and specificity and AUC. Based on the AUC, FIVC was defined as an infrarenal transverse to anteroposterior (AP) IVC ratio of ≥ 1.9, patients with a ratio < 1.9 were deemed to have an NFIVC. The cut-off value of 1.9 maximised the sum of sensitivity and specificity in predicting the mortality and had an AUC of 0.67. The use of this IVC cut-off provided a sensitivity of 52% and a specificity of 88%. A retrospective cohort study design was then used with the exposure of interest dichotomously defined based on the IVC ‘‘flatness.’’

Another study by Bhagavat et al[106], used contrast-enhanced CT scan of the abdomen and pelvis of patients with blunt abdominal injury. The purpose of the contrast study was to measure the IVC diameter and the images were examined for signs of hemoperitoneum, solid organ injury and skeletal injury. The IVC diameter was measured at the infrarenal part. The ratio of transverse (T): Anteroposterior (AP) diameter of the infrarenal vessel was estimated. The ratio of T: AP diameter was defined to be FIVC was ≥ 1.9, and non-FIVC as less than 1.9. The ratio was measured at the confluence of IVC and left renal vein.

2. Contained rupture of IVC:

The inferior vena cava is not commonly injured in the context of blunt trauma to the abdomen. Findings from inferior vena cava injury reports show the occurrence of retroperitoneal hematoma circumferential to the inferior vena cava, presence of irregularities in the vessel outline and extravasation. Among those who are clinically stable, computed tomography is useful in localising the site of injury to IVC as well as assessing any concomitant injuries. Early assessment has been found to significantly improve survival.[107]

Retro hepatic injury of the Inferior vena cava:

Increased risk of mortality is observed in injury to the IVC in the retro hepatic zone. In some instances, the mortality can cross 50%. It is essential to identify this type of injury since the clinical status of the patients may appear stable and hence, may not correlate with the severity of injuries. This is because the extension of haemorrhage would be prevented by the liver. In addition, surgical exploration without prior accurate assessment might result in uncontrolled bleeding. CT imaging in retro hepatic IVC injury manifests as the irregular contour of IVC and as hepatic laceration which may extend to the porta hepatis.[108]

ROLE OF CT DIAGNOSED FLAT IVC INPREDICTING SEVERITY AND OUTCOMES IN PATIENTS WITH BLUNT ABDOMEN:

One of the earliest studies conducted on the utility of CT in assessing a flat IVC was performed by Jeffrey RB Jr et al[109] (1988). They conducted a study of around 100 BAT patients. When CT evaluation was done, 7 cases had multiple level flattening of IVC. Among these 7 patients, major surgery was performed on 6 patients to control blood loss. The predominant source of blood loss was injury to abdominal viscera. The extent of the blood loss was assessed clearly only after CT evaluation. Among other patients without fluid loss, none had flattening of IVC at multiple levels. Authors concluded that the occurrence of a flat IVC on CT might be an indicator of severe hypovolemia due to blood loss.

Yanagawa et al[110] (2007), conducted a study on the IVC diameter among trauma patients after fluid replacement. They measured the maximal A-P diameter of the inferior vena cava during expiration. IVC diameter was measured twice, both at the time of arrival as well as after administering fluids. Patients were classified based on the recurrence of shock as responders with stable blood pressure and transient responders with recurrence of shock. Greater severity of the injury was observed in transient responders than in responders. Furthermore, the mean diameter of the inferior vena cava was significantly lesser among the transient responders compared to the responders. The mean IVC diameter of transient responders and responders were 6.5 mm and 10.7 mm, respectively. Hence, the authors report that persistently low diameter of IVC even after normalising blood pressure by fluid replacement is an indicator of insufficient fluids. Hence, measurement of IVC would be an indicator to predict the risk of recurrence of a shock compared to the other vital parameters such as blood pressure or heart rate.

Kandpal et al[111] (2008), performed a study on the role of CT findings in IVC in blunt trauma. They mentioned that among those with blunt trauma, the presence of flattening of IVC indicates hypovolemia and impending cardiovascular decompensation. The presence of a flat IVC along with the reduced aortic diameter, diffuse distension of bowels, hyper enhancement of pancreas, kidneys and hemoperitoneum together is termed as hypoperfusion complex in CT imaging.

Matsumoto et al[112] (2010), conducted a study on the predictive value of flat inferior vena cava in hemodynamic instability among BAT patients. They included 114 patients over a period of 2 years. The parameters measured were the highest antero-posterior diameter and transverse diameter measured at the level of the renal vein during CT imaging. If the ratio of the A-P and transverse diameters was less than 4:1, it was taken to be diagnostic of a flat IVC. Patients were differentiated into three groups on the basis of hemodynamic stability. It was found that the A-P diameter of the inferior vena cava among those who deteriorated hemodynamically was significantly lesser at 7.6 mm compared to those who were hemodynamically stable (15.8 mm) and those who were initially unstable but responded to fluid therapy (15.3 mm). All the patients with a flat IVC needed blood transfusion. Compared to those without a flat IVC (2% mortality), a higher mortality rate (52%) was observed in people with flat IVC. Hence, the authors recommend that diagnosing a flat IVC on initial CT in abdominal trauma will enable early identification of those who are at an increased risk of mortality.

Liao et al[113] (2011), conducted a study where they evaluated the diagnostic utility of flat IVC in blunt trauma patients. They included a total of 226 patients for the study. Among the study population, 12.8% had a flat IVC. Those who had a flat IVC had increased requirement of intensive care and increased risk of mortality. In addition, the average duration of hospital stay was longer among those with a flat IVC compared to those without a flat IVC. Due to the hypovolemia, those with a flat IVC had increased fluid requirements, blood replacement and higher injury severity scores compared to those without a flat IVC. Hence, the authors concluded that a CT finding of flat IVC can be taken to be a reliable indicator of hypovolemia and a prognostic indicator among patients with blunt abdominal trauma.

Milia et al[114] (2013), studied the clinical significance of flat IVC among those aged more than 55 years with blunt trauma. They measured the A-P and transverse diameters of the IVC 2.5 mm above the level of the renal veins. A considerable correlation was found between IVC ratio and the risk of mortality. Higher IVC ratios of 3 and 4 were associated with 2 times and 2.2 times greater mortality risk respectively. Hence, the authors concluded that a flat IVC was an independent predictor of mortality among those aged over 55 years.

Chendrasekar et al[115] (2013), conducted a study on the outcomes associated with a flat IVC among trauma patients. It was found that those with a flat IVC had higher injury severity score and revised trauma score. In addition, the survival rate was lesser among those with a flat IVC. Hence, the authors concluded that increased mortality is related to flat IVC even among patients who appear stable.

Ferrada et al[116] (2012), conducted a study on the prognostic value of flat inferior vena cava among BAT patients. A retrospective study was performed among the emergency room patients to assess the presence of flat IVC. They defined a flat inferior vena cava as having a diameter of less than 2 cm. The outcome variables assessed in this study were the need for blood transfusion, need for intensive care, the incidence of emergency surgery and mortality rates. The average age of the study population was 38 years. The incidence of flat IVC was 62.18%. Among those with flat IVC, there was a significantly higher need for emergency surgery, blood transfusion, admission to intensive care and higher mortality rates. Hence the authors concluded that the presence of a flat IVC at the time of admission is an indicator of poor prognosis.

Johnson et al [105](2013), studied the value of transverse to antero-posterior IVC ratio in predicting mortality among trauma patients. They included 161 patients with abdominal trauma and performed sonography. A transverse to antero-posterior IVC ratio cut off of 1.9 was defined by the authors based on the ROC analysis. The outcome variable assessed in the study was mortality during hospital stay. Additional parameters such as heart rate, blood pressure, haemoglobin, renal function tests and severity of injury were also measured. It was found that 30 out of 161 patients had a flat IVC. There was a significant inverse correlation between IVC ratio and parameters such as base excess, baseline bicarbonate levels and haemoglobin. IVC ratio was directly positively correlated with parameters such as the severity of injury and serum creatinine. There was 8.1 times increase in the risk of mortality in patients with flat IVC in comparison to those having normal IVC ratio when injury severity and age factors were adjusted. On the contrary, no considerable association was noticed between vitals such as heart rate, systolic BP and risk of mortality. Hence, the authors emphasised that the presence of normal vitals might not potentially exclude the risk of mortality in trauma patients. Monitoring of IVC diameter is of paramount importance in predicting the mortality risk in trauma.

Smithson et al[117] (2015), performed a correlation between the clinical hypoperfusion and CT evidence of hypoperfusion among adults with blunt abdominal trauma. They conducted a retrospective analysis of the CT scans of 52 blunt trauma patients who had a mean injury severity score of more than 15. The common CT findings were presence of free fluid, flat IVC, flat renal veins and enhancement of small bowels. It was found that those with a flat IVC had a greater risk of admission to intensive units, compared to those without a flat IVC. Furthermore, those with a flat IVC had worse acidosis, decreased haemoglobin levels at admission and increased need for blood transfusion. Hence, the authors concluded that the presence of a flat IVC in blunt trauma is a significant therapeutic and prognostic indicator requiring urgent intervention. CT is of greater value compared to sonography in blunt abdominal trauma. This is because it is easier to detect the inferior vena cava using CT compared to sonography.

LACUNAE IN LITERATURE:

Trauma is an important cause of mortality and morbidity in developing countries like India. Early intervention in blunt abdominal trauma patients by immediate evaluation of hemodynamic status is required. Patient vitals such as heart rate, central venous pressure, blood pressure and pulse pressure have been shown to be inadequate indicators of the volume status. The measurement of inferior vena cava diameter has been shown to have a close relation with hypovolemia. The measurement of IVC diameter using ultrasound is not feasible at all times in cases of blunt trauma due to the presence of intestinal gas and due to abdominal fat. But CT has been proven to be of great utility in assessing abdominal injuries in this respect. Hence, this study seeks to assess the utility of CT measured IVC diameter in predicting hypotension among patients with blunt trauma.

MATERIALS & METHODS

Study site: This study was conducted in the department of Radiodiagnosis at KLE's Dr.Prabhakar Kore Hospital & MRC, Belagavi

Study population: All the eligible patients with blunt abdominal trauma in the study setting were considered as the study population.

Study design: The current study was a cross sectional study.

Sample size: A total of 30 patients with blunt abdominal trauma were studied during a period of one year (2018-19) at our hospital. Considering the rarity of the disease condition in question and limited time available for data collection, we have decided to include all the available cases, satisfying the inclusion criteria, reported during the study period in our study.

Sampling method: All the eligible subjects were recruited by universal sampling method.

Study duration: The data collection for the study was done between 1st January 2018 to 30th December 2018 for a period of 1 year.

Inclusion Criteria:

- Patients with history of blunt abdominal trauma referred by the physician for a contrast enhanced CT scan of the abdomen,
- Patients with history of blunt abdominal trauma who presented with intra-abdominal free fluid on abdominal sonography further referred for CT.

Exclusion criteria:

- Non-Consenting Patients
- Abdominal trauma patients who underwent only non-contrast CT
- Hemodynamically unstable patients who directly proceed to the operating room for surgery.

Data collection tools: All the relevant parameters were documented in a structured study proforma.

METHODOLOGY:

CT EQUIPMENT-Using a 64 slice CT Siemens somatom scanner system and using Iopromide injection for IV contrast, scan of the abdomen and pelvis were performed on the patients who presented with a history of blunt abdominal trauma with the patient in supine position.

CT TECHNIQUE -Axial sections of CE-CT abdomen using 120Kvp and 400mAS with 1.5mm cuts were studied from the lung base to the symphysis pubis.

Imaging was performed in the plain, arterial phase and venous phases. The delayed excretory phase was performed in cases of renal injury.

EVALUATION CRITERIA:

1. In our study the Transverse: Anteroposterior ratio of the IVC was measured infrarenally. The normal value of ratio was considered as 1.9. We considered > or = 1.9 as flat IVC and <1.9 -as non- flat IVC, as proposed by Jhonson JJ et al.[105]

2. **Presence of the following was evaluated**

    a. Hemoperitoneum.

    b. Solid-organ injuries classified as per AAST grading.

    C. Skeletal injuries of ribs, pelvic bones and vertebrae.

Ethical considerations: Study was approved by institutional human ethics committee. It was mandatory for the participants of the study to sign an Informed written consent. The risks and benefits involved in the study and the voluntary nature of participation were explained to the participants before obtaining consent. The study maintains confidentiality of all the participants.

Statistical Methods:

Hypotension was the primary outcome variable and flat IVC was the primary explanatory variable. Solid-organ injury, presence of hemoperitoneum were considered as other variables of interest.

Descriptive analysis: Descriptive analysis was carried out by mean and standard deviation for quantitative variables, frequency and proportion for categorical variables. Data was also represented using appropriate diagrams like a bar diagram, pie diagram and box plots.

Categorical outcomes were compared between study groups using Chi square test /Fisher's Exact test (If the overall sample size was < 20 or if the expected number in any one of the cells is < 5, Fisher's exact test was used.)

Hypotension was considered as the outcome. Flat IVC was considered as a screening test. The sensitivity, specificity, predictive values and diagnostic accuracy of the flat IVC were calculated along with their 95% CI were presented.

P value < 0.05 was considered statistically significant. IBM SPSS version 22 was used for statistical analysis.[118]

RESULTS

A total of 30 subjects with blunt abdominal trauma were involved in the analysis.

Table 1: Age distribution of study population (N=30)

Parameter	Mean ± SD	Median	Minimum	Maximum	95% C.I	
					Lower	Upper
Age (In Years)	26.93 ± 11.51	26.50	5.00	65.00	22.64	31.23

The mean age was 26.93 ± 11.51 years. The minimum age was 5 years and the maximum age was 65 years in the study population. (95% CI 22.64 to 31.23). (Table1)

Table 2: Descriptive analysis of age group (years) in the study population (N=30)

Age Group (Years)	Frequency	Percentage
<20	7	23.3%
21 to 40	21	70.0%
41 to 60	1	3.3%
61 and above	1	3.3%

Among the study population, 7(23.3%) were <20 years of age, 21(70%) aged between 21 and 40 years, 1(3.3%) was aged between 41 and 60 years and 1(3.3%) was aged more than 61 years. (Table2 &Figure1)

Figure 1: Bar chart of age group (years) in the study population (N=30)

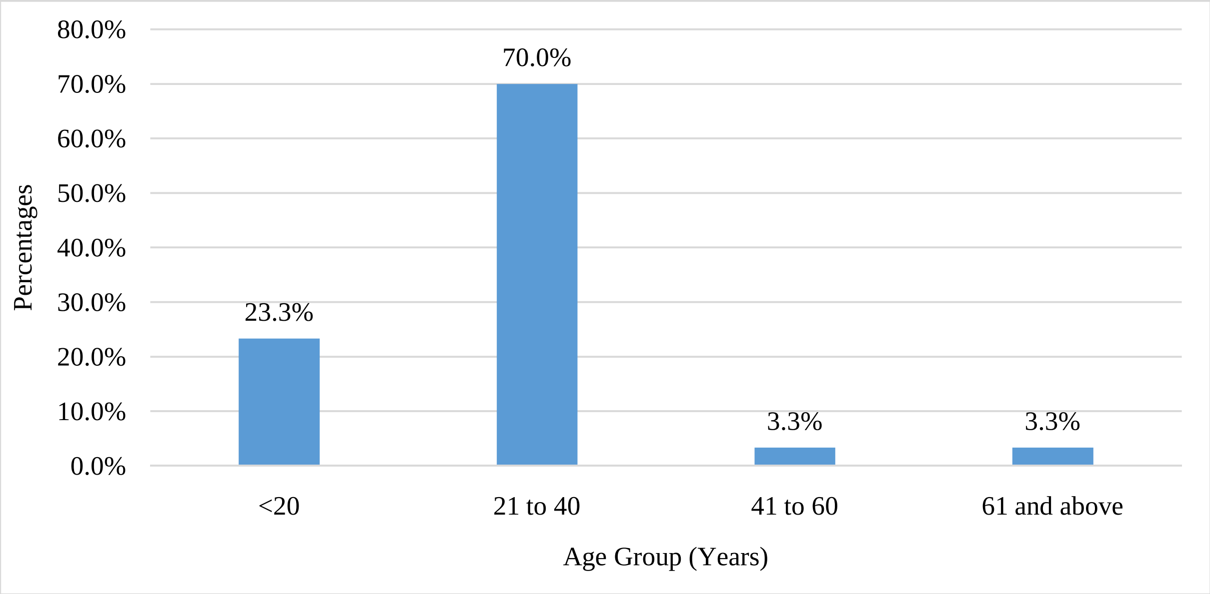


Table 3: Gender distribution of the study population (N=30)

Gender	Frequency	Percentage
Male	25	83.3%
Female	5	16.7%

Among the study population, 25(83.3%) participants were males and remaining 5(16.7%) participants were females. (Table 3 & Figure 2)

Figure 2: Pie chart of gender distribution (N=30)

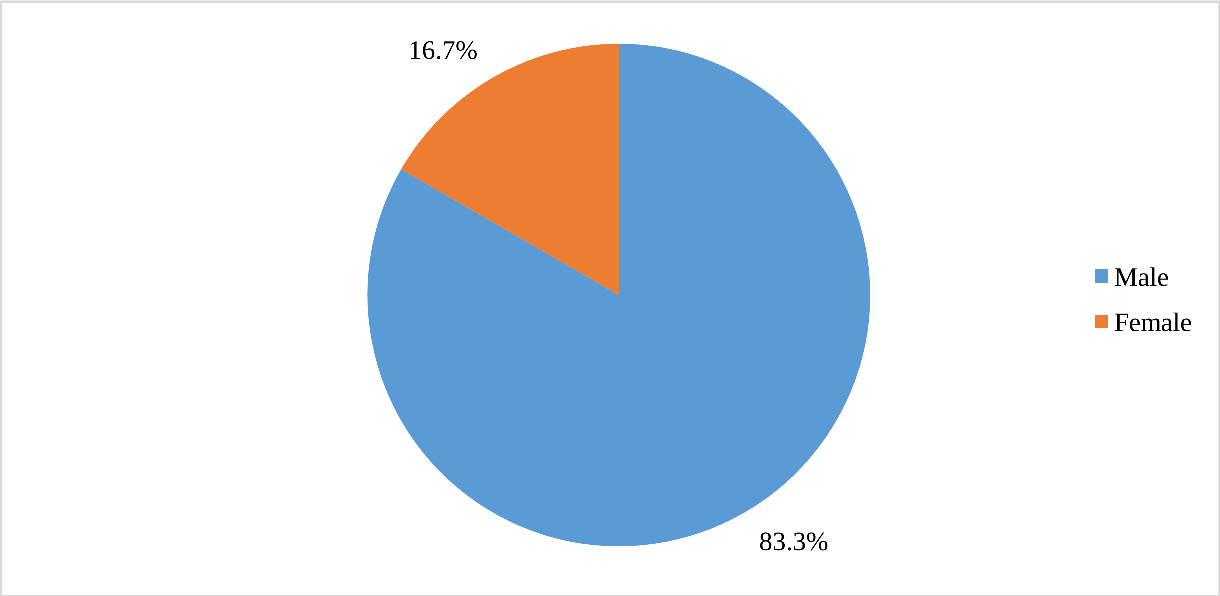


Table 4: Mechanism of injury in the study population (N=30)

Mechanism of Injury	Frequency	Percentage
RTA	29	96.7%
FALL	1	3.3%

Among the study population, 29(96.7%) participants met with road traffic accidents and remaining 1(3.3%) participant met with fall. (Table 4 & Figure 3)

Figure 3: Pie chart of the mechanism of injury (N=30)

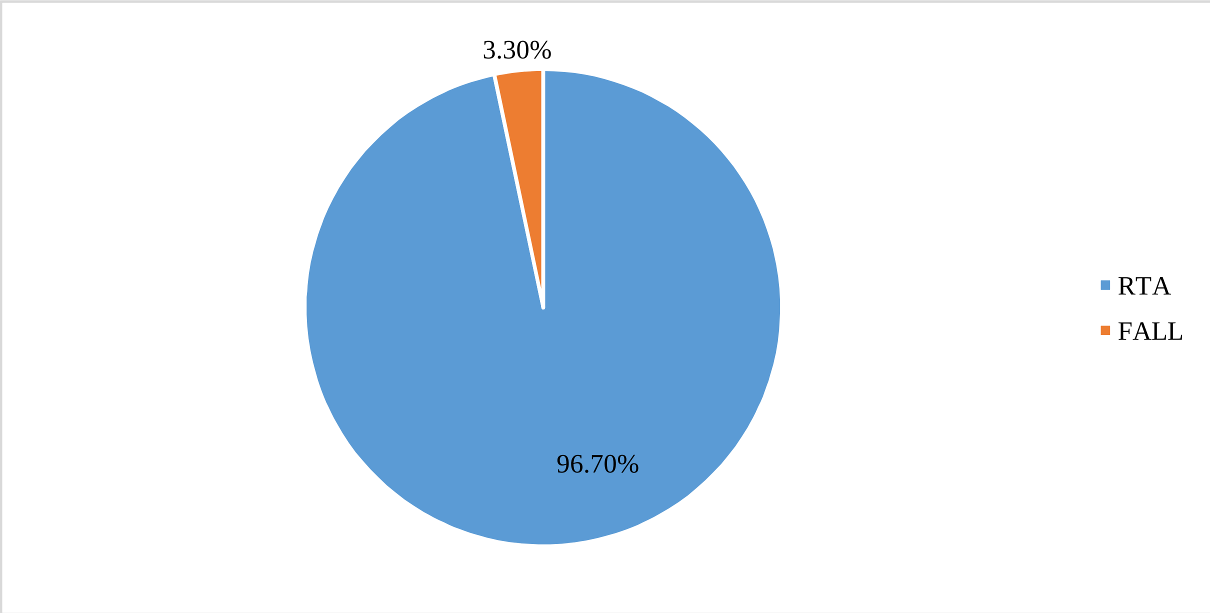


Table 5: Evidence of solid organ injury in the study population (N=30)

Evidence of solid organ injury	Frequency	Percentage
Yes	30	100.00%
No	0	0.00%

Among the study population, all the 30(100%) patients had evidence of solid organ injury. (Table 5)

Table 6: Descriptive analysis of organ injury in the study population (N=30)

Organ injury	Yes N (%)	No N (%)	Total
Splenic	16(53.3%)	14(46.7%)	30
Liver	15(50.0%)	15(50.0%)	30
Pancreatic	4(13.3%)	26(86.6%)	30
kidney	5(16.7%)	25(83.3%)	30

Among the study population, 16(53.3%) had splenic injury, 15(50%) had liver injury, 4(13.3%) had pancreatic injury and 5(16.7%) had kidney injury. (Table 6 & Figure 4)

Figure 4. Staked bar chart of associated solid organ injuries in the study population (N=30)

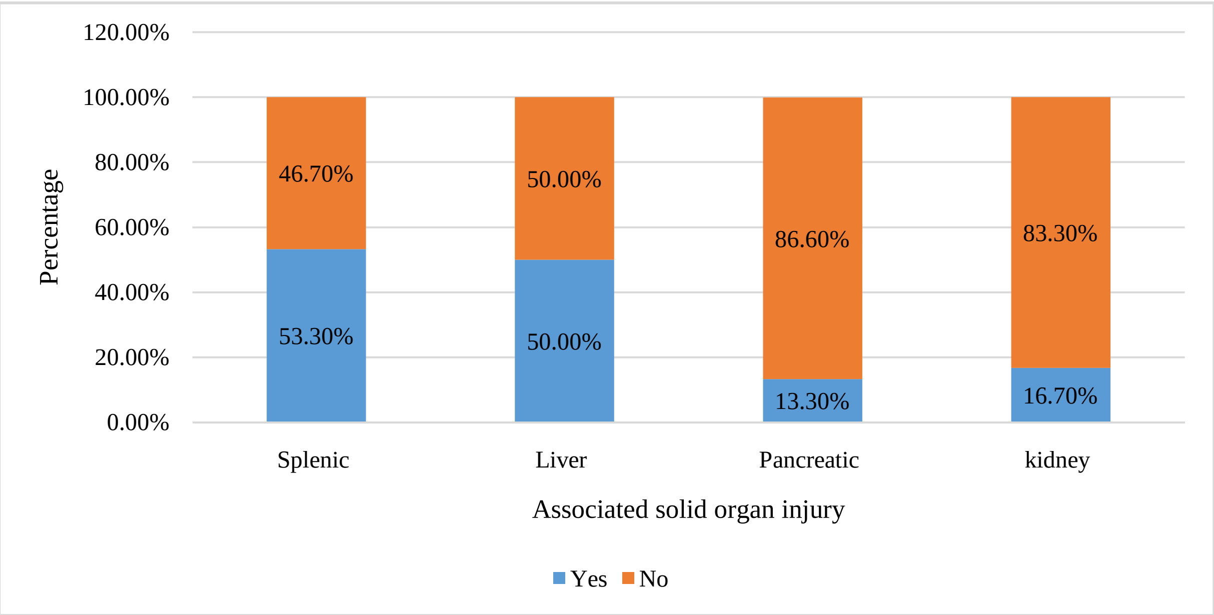


Table 7: Descriptive analysis of the presence of hemoperitoneum in the study population (N=30)

Presence of hemoperitoneum	Frequency	Percentage
Minimal	7	23.3%
Mild	12	40.0%
Moderate	8	26.7%
Nil	3	10.0%

Among the study population, 7(23.3%) had minimal hemoperitoneum, 12(40%) had mild hemoperitoneum, 8(26.7%) had moderate hemoperitoneum, and 3(10%) had no hemoperitoneum. (Table 7 & Figure 5)

Figure 5: Bar chart of the presence of hemoperitoneum in the study population (N=30)

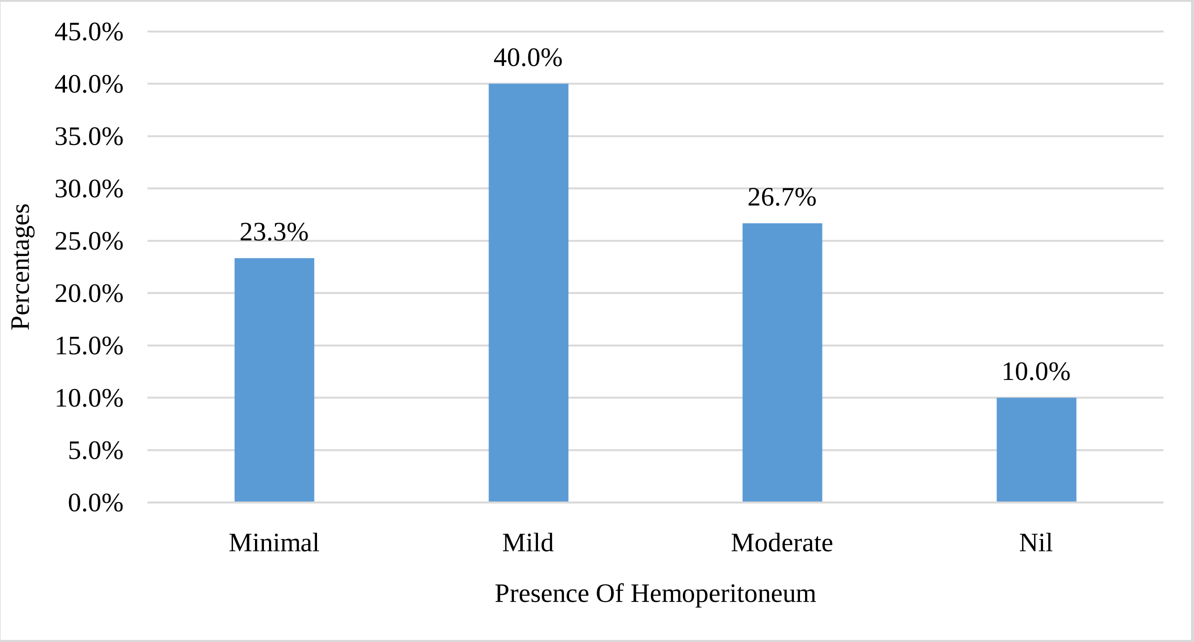


Table 8: Descriptive analysis of presence of flat IVC (FIVC) in the study population (N=30)

Flat IVC (FIVC)	Frequency	Percentage
Flat IVC	23	76.7%
Non-flat IVC	7	23.3%

Among the study population 23(76.7%) had flat IVC and 7 had non-flat IVC. (Table 8 & Figure 6)

Figure 6: Pie chart of the presence of flat IVC (FIVC) in the study population (N=30)

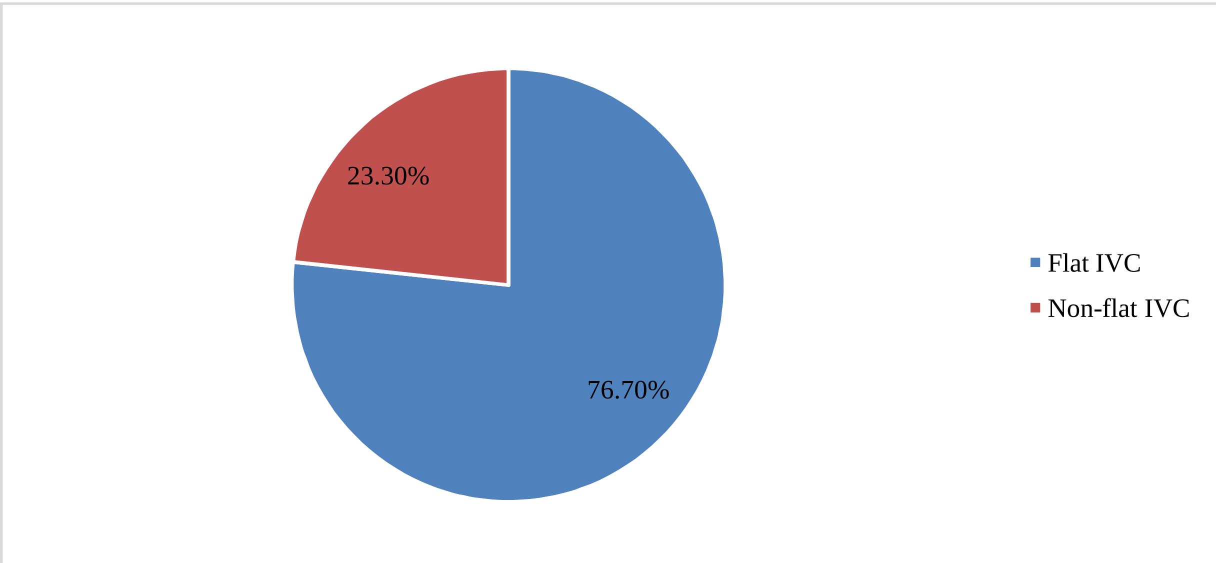


Table 9: Descriptive analysis of the presence of hypotension in the study population (N=30)

Presence of hypotension	Frequency	Percentage
Hypotension (BP <90/60 mm/ Hg)	28	93.3%
No hypotension(BP >=90/60 mm/Hg)	2	6.7%

Among the study population ,28(93.3%) had hypotension. (Table 9 & Figure 7)

Figure 7: Pie chart of the presence of hypotension in the study population (N=30)

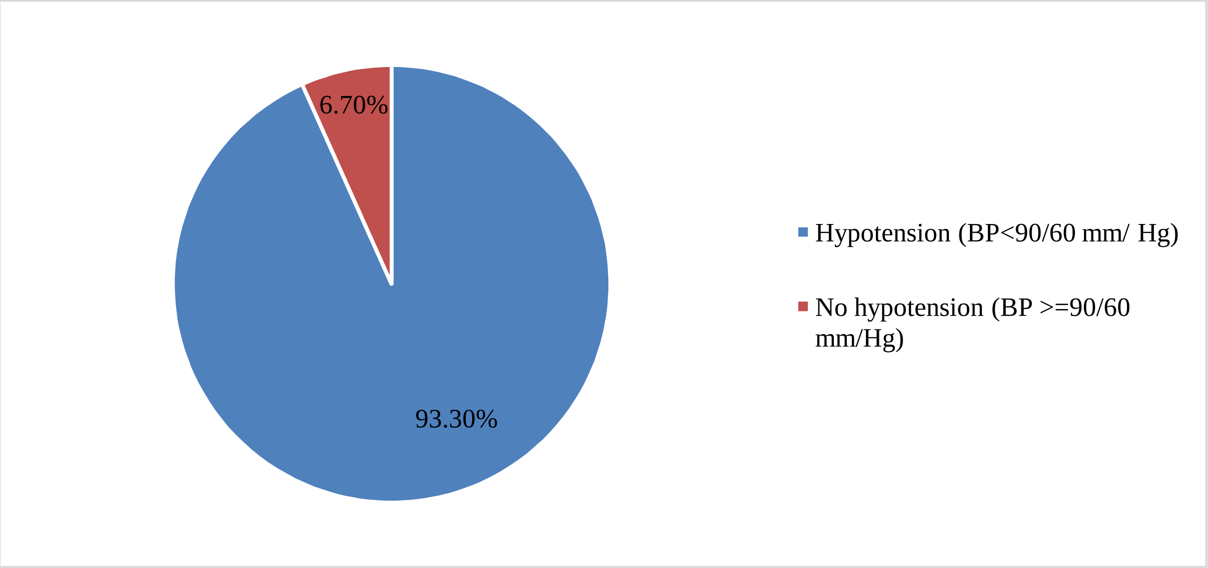


Table 10: Descriptive analysis of patients with presence of both hypotension+ flat IVC in the study population (N=30)

Hypotension+ Flat IVC	Frequency	Percentage
Hypotension+ Flat IVC	23	76.7%
No hypotension+ Flat IVC	7	23.3%

Among the study population 23(76.7%) had both hypotension and flat IVC. (Table10 & Figure 8)

Figure8: Pie chart of patients with both hypotension+ flat IVC in the study population (N=30)

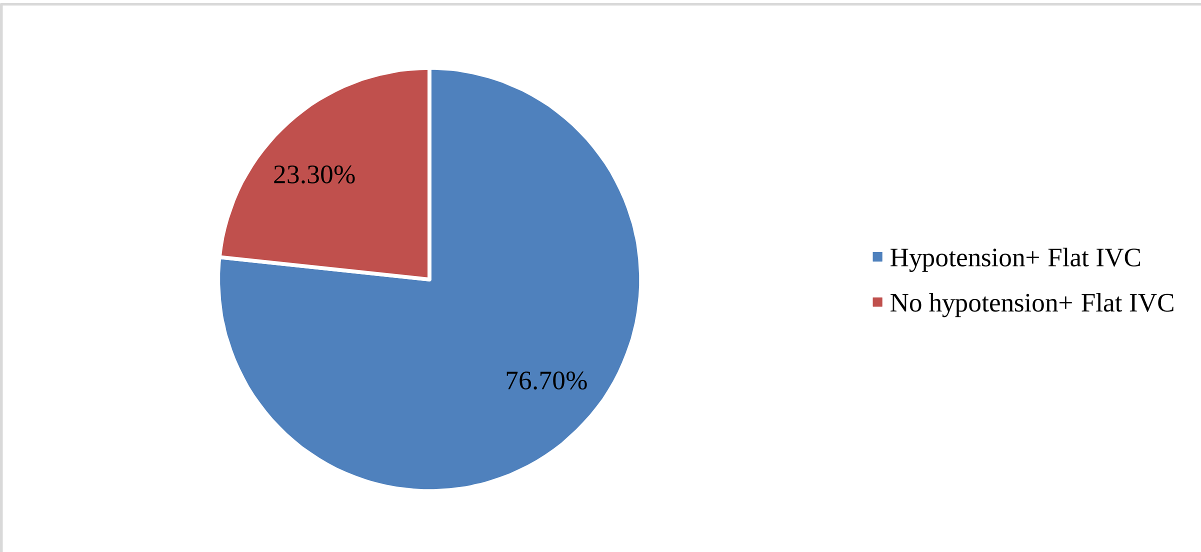


Table11: Proportion of flat IVC among patients with different solid organ injuries (N=30)

Associated solid organ injury	Presence of flat IVC (FIVC)		Fisher exact P value
	Flat IVC	**Non-Flat IVC**	
Splenic (N=16)	13 (81.25%)	3 (18.75%)	0.675
Liver (N=15)	12 (80%)	3 (20%)	1.00
Kidney (N=5)	3 (60%)	2 (40%)	0.565
Pancreatic(N=4)	3 (75%)	1 (25%)	1.00

Among the patients with splenic injury, 13 (81.25%) had flat IVC. Among the patients with liver injury, 12(80.0%) had flat IVC. Among the patients with kidney injury,3 (60%) had flat IVC. Among the patients with pancreatic injury 3 (75%) had flat IVC. The difference in the proportion of splenic, liver, pancreatic and kidney injuries between flat IVC was statistically not significant. (P value >0.05). (Table 11 & Figure 9)

Figure 9: Staked bar chart of FIVC among patients with different solid organ injuries (N=30)

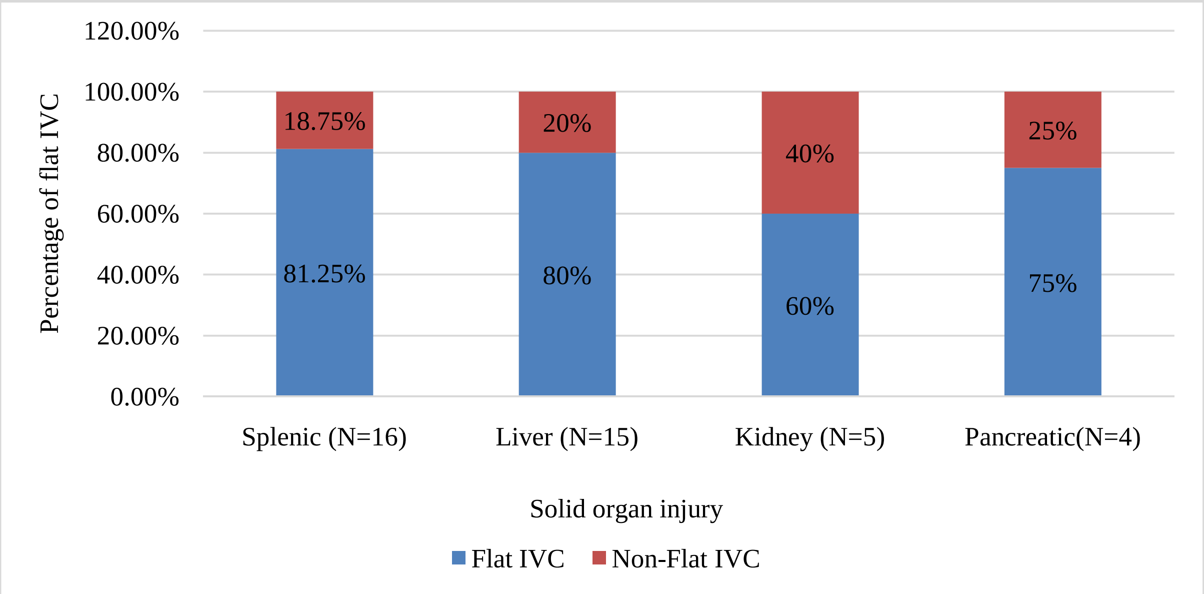


Table 12: Proportion of hypotension among patients with different solid organ injuries (N=30)

Associated solid organ injury	Hypotension		Fisher exact P value
	Hypotension	No hypotension	
Splenic (N=16)	15 (93.75%)	1 (6.25%)	1.00
Liver (N=15)	14 (93.33%)	1 (6.67%)	1.00
Kidney (N=5)	5 (100%)	0 (0%)	**
Pancreatic(N=4)	4 (100%)	0 (0%)	**

*No statistical test was applied- due to 0 subjects in the cells

Among the patients with splenic injury 15(93.8%) had hypotension. Among the patients with liver injury, 14(93.8%) had hypotension. Among the patients with kidney injury, 5(100%) had hypotension. Among the patients with pancreatic injury, 4(100%) had hypotension. The difference in the proportion of splenic and liver injury between hypotension was statistically not significant. (P value >0.05). (Table 12 & Figure 10)

Figure 10: Staked bar chart of presence of hypotension among people with different solid organ injuries (N=30)

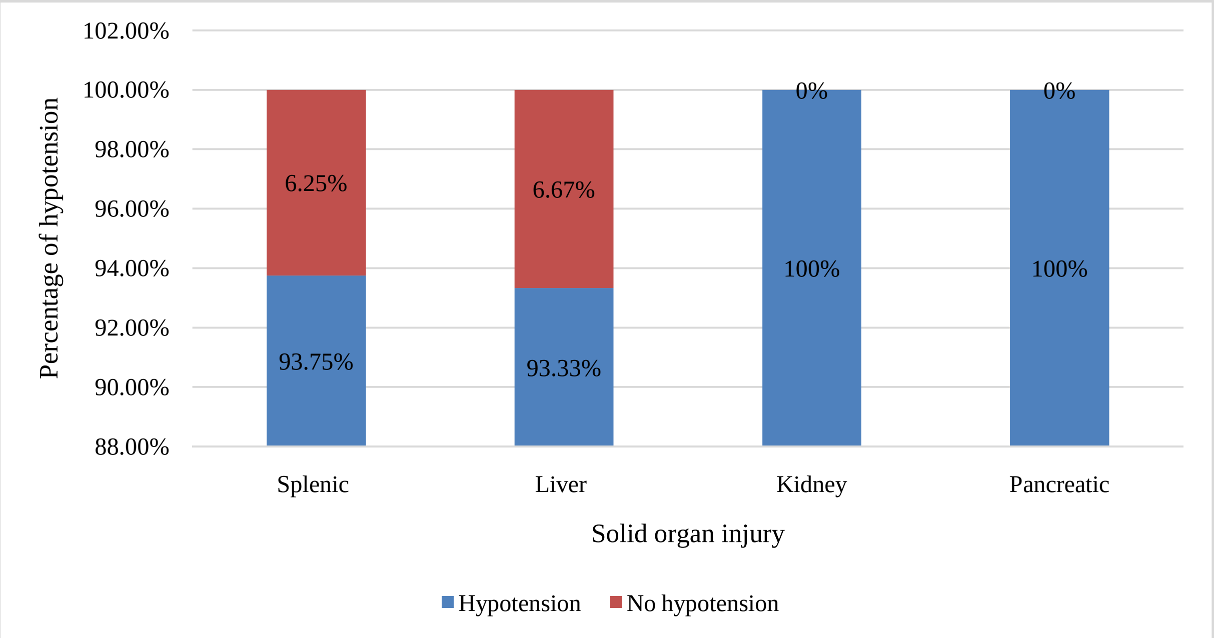


Table13: Comparison of associated organ injuries between flat IVC(FIVC) + hypotension (N=30)

Associated solid organ injury	Flat IVC (FIVC) +Hypotension		Fisher exact P value
	Flat IVC (FIVC) +Hypotension	Non-Flat IVC (NFIVC) +Hypotension	
Splenic (N=16)	13 (81.25%)	3 (18.75%)	0.675
Liver (N=15)	12 (80%)	3 (20%)	1.00
Kidney (N=5)	3 (60%)	2 (40%)	0.565
Pancreatic(N=4)	3 (75%)	1 (25%)	1.00

Among the patients with splenic injury 13 (81.25%) had flat IVC + hypotension. Among the patients with liver injury, 12(80.0%) had flat IVC + hypotension. Among the patients with kidney injury,3(60%) had flat IVC + hypotension. Among the patients with pancreatic injury 3(75%) had flat IVC + hypotension. The difference in the proportion of splenic, liver, kidney and pancreatic injuries between flat IVC + hypotension was statistically not significant. (P value >0.05). (Table 13 & Figure 11)

Figure 11: Staked bar chart both Flat IVC+ hypotension among patients with different solid organ injuries (N=30)

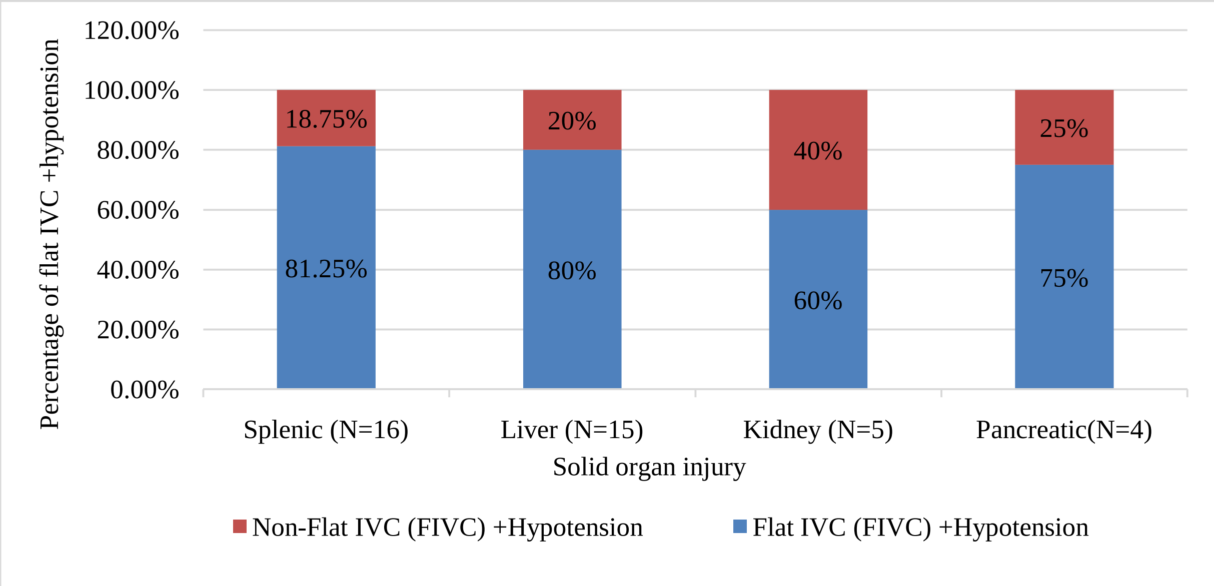


Table 14: Association between flat IVC (FIVC) and hypotension (N=30)

Flat IVC (FIVC)	Presence ofhypotension	
	Hypotension	No hypotension
Flat IVC	23 (82.14%)	0 (0%)
Non-flat IVC	5 (17.86%)	2 (100%)

Among 28 patients with hypotension 23 (82.14%) had flat IVC, 5(17.86%) patients with hypotension had non-flat IVC (Table 14 & Figure 12)

Figure 12: Cluster bar graph for comparison of presence of hypotension with Flat IVC (FIVC) (N=30)

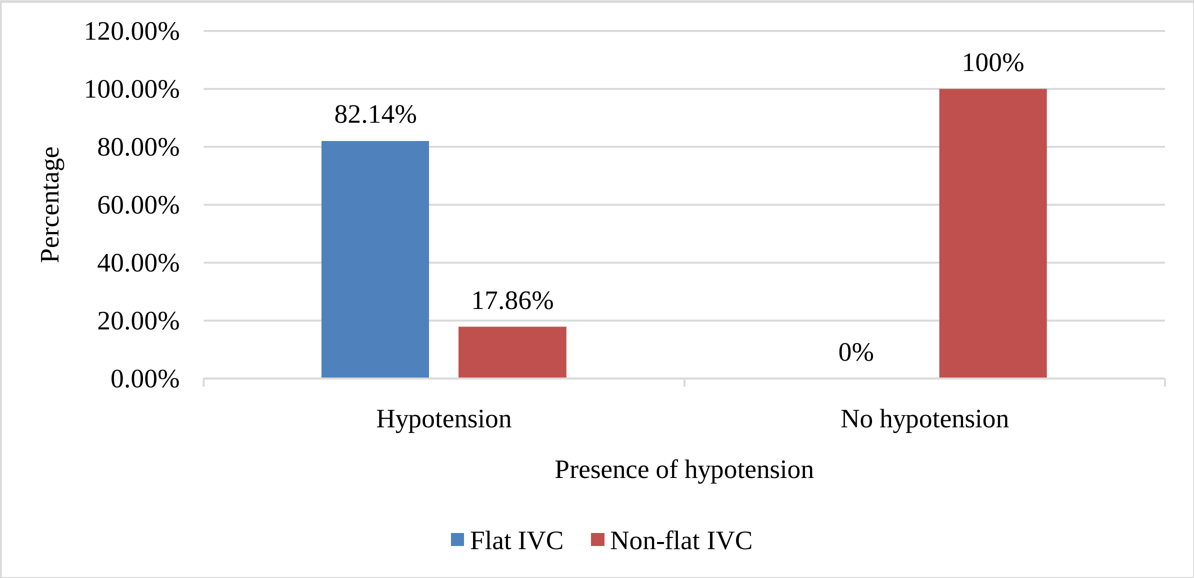


Table 15: Predictive validity of flat IVC (FIVC) in predicting the presence of hypotension (N=30)

Parameter	Value	95% CI	
		Lower	Upper
Sensitivity	82.14%	63.11%	93.94%
Specificity	100.00%	15.81%	100.00%
False positive rate	0.00%	0.00%	84.19%
False negative rate	17.86%	6.06%	36.89%
Positive predictive value	100.00%	85.18%	100.00%
Negative predictive value	28.57%	3.67%	70.96%
Diagnostic accuracy	83.33%	65.28%	94.36%

Flat IVC had sensitivity of 82.14% (95% CI 63.11% to 93.94%), specificity of 100.00% (95 CI 15.81% to 100%) in detecting hypotension. The positive predictive value was 100.00% (95 CI 85.18% to 100%), Negative predictive value was 28.57% (95 CI 3.67% to 70.96%), and the total diagnostic accuracy was 83.33% (95 CI 65.28% to 94.36%). (Table 15)

Table 16: Descriptive analysis of a combination of solid organ injuries in the study population (N=30)

Combination of associated organ injuries	Frequency	Percentage
Splenic alone	10	33.3%
Liver alone	8	26.7%
Splenic +Liver	4	13.3%
Pancreatic alone	3	10.0%
Kidney alone	1	3.3%
Liver + Kidney	1	3.3%
Pancreatic +Kidney +Liver	1	3.3%
Splenic + Kidney	1	3.3%
Kidney + Splenic +Liver	1	3.3%

Majority of the study population 10(33.3%) had splenic injury alone, 8(26.7%) had liver injury alone, 4(13.3%) had splenic + liver injury and 3(10%) had pancreatic injury alone. (Table 16 & Figure 13)

Figure 13: Bar graph representing combination of associated organ injuries in the study population (N=30)

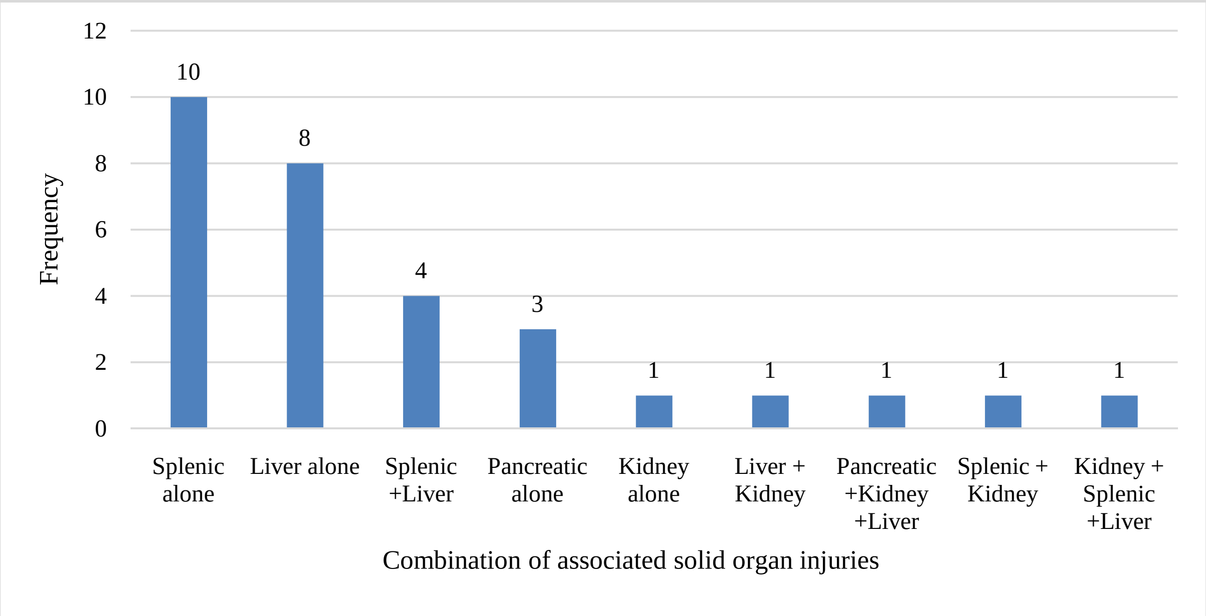


Table 17: Comparison of combination of associated organ injuries between the presence of hypotension (N=30)

Combination of associated organ injuries	Presence of Hypotension	
	Hypotension	No hypotension
Splenic alone (N=10)	10 (100%)	0 (0%)
Liver alone(N=8)	7 (87.5%)	1 (12.5%)
Splenic +Liver(N=4)	4 (100%)	0 (0%)
Pancreatic alone(N=3)	3 (100%)	0 (0%)
Kidney alone (N=1)	1 (100%)	0 (0%)
Liver + Kidney (N=1)	1 (100%)	0 (0%)
Pancreatic +Kidney +Liver(N=1)	1 (100%)	0 (0%)
Splenic + Kidney(N=1)	0 (0%)	1 (100%)
Kidney + Splenic +Liver(N=1)	1 (100%)	0 (0%)

*No statistical test was applied- due to 0 subjects in the cells

All the patients with only splenic injury alone (100%) had hypotension. Among the patients with liver injury, 7(87.5%) had hypotension and among patients with splenic and liver injury 4 (100%) had hypotension. (Table 17 & Figure 14)

Figure 14: Bar graph of presence of hypotension in patients with combinations of solid organ injuries (N=30)

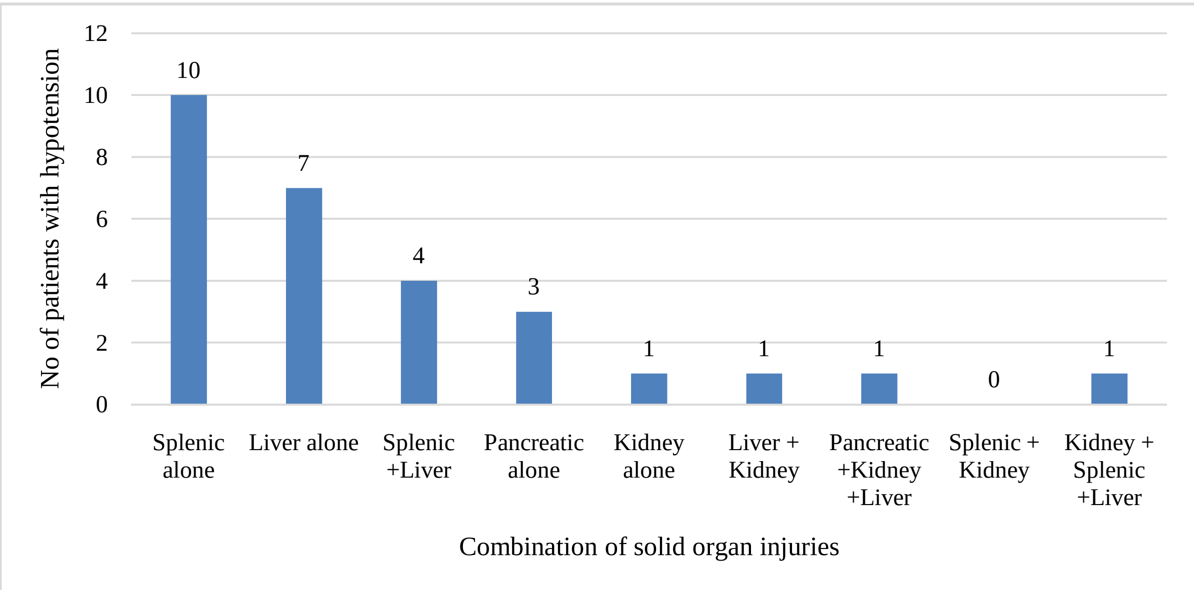


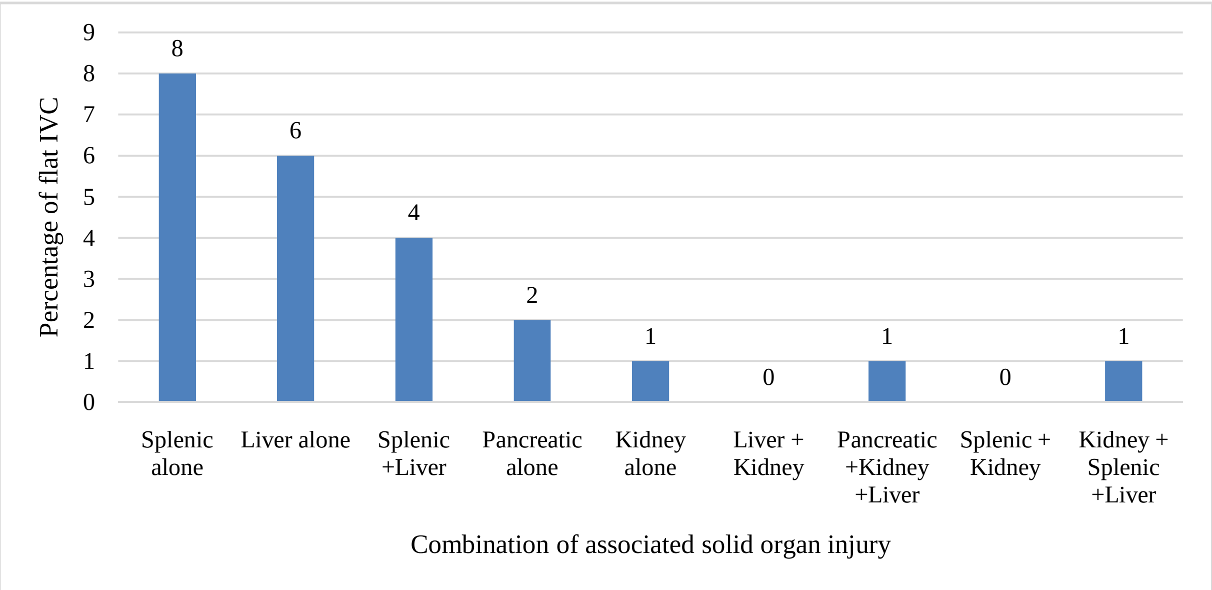
Table 18: Comparison of combination of associated organ injuries between flat IVC (FIVC) (N=30)

Combination of associated organ injuries	Flat IVC (FIVC)	
	Flat IVC	Non-flat IVC
Splenic alone (N=10)	8 (80%)	2 (20%)
Liver alone(N=8)	6 (75%)	2 (25%)
Splenic +Liver(N=4)	4 (100%)	0 (0%)
Pancreatic alone(N=3)	2 (66.67%)	1 (33.33%)
Kidney alone (N=1)	1 (100%)	0 (0%)
Liver + Kidney (N=1)	0 (0%)	1 (100%)
Pancreatic +Kidney +Liver(N=1)	1 (100%)	0 (0%)
Splenic + Kidney(N=1)	0 (0%)	1 (100%)
Kidney + Splenic +Liver(N=1)	1 (100%)	0 (0%)

*No statistical test was applied- due to 0 subjects in the cells

Majority of patients with only splenic injury 8 (80%) had flat IVC. Among patients with only liver injury, 6 (75%) had flat IVC and among patients with splenic + liver injury, 4 (100%) had flat IVC. (Table 18 & Figure 15)

Figure 15: Bar graph of the presence of flat IVC in patients with combinations of solid organ injuries (N=30)



DISCUSSION

Mortality and morbidity due to road accidents have been on the rise in India and also globally. Blunt abdominal trauma is one of the commonly encountered injuries among the victims of road traffic accidents.[23] These victims often may present with an apparently stable clinical picture, but tend to present with compromised hemodynamic status due to associated internal organ injuries. Although the vital signs such as blood pressure and pulse rate are routinely used to assess the hemodynamic stability in patients, their ability to predict the severity of hemodynamic status is limited.[72]In these situations, the computer tomography scan of the abdomen with analysis of venous phase diameter of IVC has guided the physicians to predict the hemodynamic status more accurately.[105] Hence, in the present study we attempted to evaluate the independent predictive value of IVC diameter in the assessment of hypotension among those with blunt abdominal trauma.

This study included 30 subjects with a history of blunt abdominal injury with a mean age of 26.93 ± 11.51 years for analysis. There was a strong male preponderance, as 83.3% of the study population were males. Higher male preponderance to road traffic injuries had been reported by multiple previous studies published on the subject.[48,51] Even global studies have reported the predominant involvement of men in their second and third decades of life in road traffic accidents.[15, 17]

Table 19: Comparison of age and gender composition of patients presenting with blunt abdominal trauma due to road traffic accidents across different studies.

Studies	Age in years	Male
Bansod et al[51]	21-40	87.4%
Srivastav et al[48]	11-40	94%
Hemmati H et al[17]	34.1 ± 1.68	88.2%
Costa G et al[15]	38.7 ± 16.2	83.6%
Present study	21-40 years	70 %

The present study showed an increased percentage of male victims with blunt abdominal injury which was in accordance to the other previous studies. Also, in comparison to other studies, the present study witnessed that most of the people who encountered blunt abdominal injury were in productive age group, which implies that blunt abdominal injury may have an impact on the individual and the national economic growth.

In the current study, the major portion of the blunt abdominal injuries (96.7%) were due to road accidents and 3.3% were due to fall. The relative contribution of road traffic accidents to the blunt abdominal trauma reported from many other hospital-based studies is similar to the current study. Among the road traffic accident patients, blunt abdominal injury is more commonly reported as compared to penetrating type.[15, 18]

All the subjects included in the current study had involvement of at least one of the four solid organs i.e. liver, spleen, pancreas and kidney. The splenic injury was the most common solid organ involvement found in 53.3% of the subjects. Liver injury was found in 50% and kidney injury in 16.7%. Least commonly injured solid organ was pancreas seen in 13.3% of the subjects. Similar findings were observed by many previous studies published on the subject. [21, 48, 119]

This illustrates that the blunt injury to the abdomen have a greater chance of splenic organ injury compared to injury to the pancreas, liver and kidney. In contrast to this, in a study by Solanki et al[25] and Smith et al[120], a greater percentage of liver injury among blunt abdominal injury cases have been recorded.

Among the splenic injury patients, 1(6.25%) had AAST grade I injury, 3(18.75%) had grade II, 6(37.5%) had grade III and 6(37.5%) had grade IV injury. The percentage of Grade II and Grade III (n=5, 33.33% each) injuries were higher among liver injury patients. The percentage of grade III (n=2,50%) injury was greater among patients with pancreatic injury compared to Grades II and IV (n=1, 25% each). Whereas, the percentage of grade I and III (n=2,40% each) injuries was equal among patients with kidney involvement. In a study conducted in Qatar, in which many numbers of cases of blunt injury due to road accidents were registered, there was a greater percentage of grade I and III splenic injuries than grade IV.[61] Along with splenic injury, 67 (35.1%) patients also had involvement of other solid organs, such as liver (19.9%), kidneys (17.8%), and pancreas (4.2%). Another study by Al-Qahtani et al[121], reported a greater proportion of grade IV/V blunt splenic injury (62%), followed by lower grades (I–III). Lower grades of blunt splenic injuries are ideally managed by non-operative methods of stabilising the patient’s hemodynamic status. This in turn decreases the need for surgical resection & thus reduces the incidence of postoperative complications. In cases with grade IV splenic injury, operative management was recorded to be successful.[122-124]

In the present study, 90% of the blunt abdominal trauma patients (BAT patients) had hemoperitoneum. Out of this 23.3% had minimal, 40% had mild degree and 26.7% had moderate degree hemoperitoneum. In a similar study by Srivastava SK et al[48], who had studied blunt injury on 48 patients, only 8 patients had hemoperitoneum . In another study by Gupta S et al[125], out of 63 patients studied, 40 (63%) had hemoperitoneum. Differences in the severity of injury and proportion of involvement of different solid organs etc. may be responsible for these differences in the proportion of hemoperitoneum across the studies.

In the present study, we aimed to find the predictive validity of IVC diameter along with grades of solid organ injury through CT scan so that the treating physicians could decide between non- surgical or surgical treatment of patients with blunt abdominal injury. The ability of the IVC diameter in predicting hypovolemia, the presence of blood and hemodynamic decline was well recognised by earlier studies.[73, 110, 113] The FIVC defined by these studies were very subjective and the measurements of IVC diameter was from different anatomical positions. Few studies have proposed flat IVC as an indicator or predictor of mortality, but its independent association had not been established.[112, 113] A retrospective study by Johnson et al[105], attempted to establish an independent association of IVC diameter by adjusting the known confounders. The authors determined a cut off IVC ratio by using ROC analysis and area under the curve (AUC) analysis. This cut off values were used for diagnostic and prognostic purposes. Based on the analysis, FIVC was defined as an infrarenal transverse to antero-posterior diameter IVC ratio of >1.9 and that <1.9 was labelled to be non FIVC.

In our study, we used the ratio of IVC proposed by Johnson et al[105], to define flat IVC. This was because this study analysed amongst the other anatomic location of IVC (intrahepatic IVC or IVC near the renal vein) with hypoperfusion markers. Hence among the other anatomical location, infrarenal measurements had the strongest correlation with the known markers of hypoperfusion (haemoglobin, bicarbonates, creatinine, base excess). With AUC analysis both sensitivity and specificity of IVC diameter in predicting death was highest at the ratio of 1.9.

In the current study, the mean antero-posterior (AP) IVC diameter in cms was 1.27 ± 0.37, ranging from 0.70 to 1.9 cm. The mean IVC diameter- transverse (T) in cms was 2.67 ± 0.47 ranging from 1.76 to 3.50 cm. The mean IVC diameter ratio (T: AP) was 2.21 ± 0.49, ranging from 1.31 to 3.49 in the study population. The mean systolic blood pressure was 87.33 ± 7.34 mm of Hg. The minimum level of systolic BP was 80mm Hg, and the maximum was 114 mm Hg. The mean diastolic blood pressure was 60.93 ± 9.24 mm Hg. The minimum level of diastolic BP was 50 mm of Hg, and the maximum was 96 mm of Hg.

Among the patients with splenic injury, 13 (81.25%) had flat IVC. Among the patients with liver injury, 12(80.0%) had flat IVC. Among the patients with kidney injury, 3 (60%) had flat IVC. Among the patients with pancreatic injury 3 (75%) had flat IVC. The difference in the proportion of splenic, liver, pancreatic and kidney injuries between flat IVC was statistically not significant. (P value >0.05). Among the patients with splenic injury 15(93.8%) had hypotension. Among the patients with liver injury, 14(93.3%) had hypotension. Among the patients with kidney injury, 5(100%) had hypotension. Among the patients with pancreatic injury, 4(100%) had hypotension. The difference in the proportion of splenic and liver injury between hypotension was statistically not significant (P value >0.05). Among the people with splenic injury 13 (81.25%) had flat IVC + hypotension. Among the patients with liver injury, 12(80.0%) had flat IVC + hypotension. Among the patients with kidney injury, 3(60%) had flat IVC + hypotension. Among the patients with pancreatic injury 3(75%) had flat IVC + hypotension. The difference in the proportion of splenic, liver, kidney and pancreatic injuries between flat IVC + hypotension was statistically not significant (P value >0.05). A similar study by Bhagavat et al[119], evaluated 25 cases of blunt abdominal trauma, where 40 % of patients had hemoperitoneum. Majority of the patients (56%) had splenic injury, of which 10 % of them had FIVC. Among the liver injury (25 %) patients, 20 % had FIVC and among of renal injury (20%) patients, 5% of them had FIVC. Our study findings were in comparison to the study by Bhagavat et al.[119]

Flat IVC had sensitivity of 82.14% (95% CI 63.11% to 93.94%), specificity of 100.00% (95 CI 15.81% to 100%) in detecting hypotension. The positive predictive value was 100.00% (95 CI 85.18% to 100%), Negative predictive value was 28.57% (95 CI 3.67% to 70.96%), and the total diagnostic accuracy was 83.33% (95 CI 65.28% to 94.36%). The utility of flat IVC in predicting hypotension has been studied by very few studies in the past. In a study, the predictive value of IVC diameter was studied during blood donation. The diameter of IVC reduced after blood donation and inference was made by this study that measurement of IVC diameter would be helpful in an acute blood loss situation.[74]

Similarly in another study, the trauma patients who presented with a flat IVC were at 2.87 times greater risk of developing occult shock and at 2.26 times higher risk of developing complications compared to those who had a normal IVC diameter.[77] The sensitivity and specificity of flat IVC in the present study indicate high utility of IVC diameter measurements among the trauma and acute blood loss victims. Hence, the diameter of IVC on computer tomography could predict hypotension among the majority of patients with blunt abdominal trauma.

CONCLUSION

This cross-sectional study of 30 subjects with blunt abdominal injury had greater predisposition among males. Blunt type of injury was mostly encountered in road accidents. Highest proportion of the victims were in the age group of 21 to 40 years. All the patients had evidence of solid organ injury. Splenic injury was the most common solid organ injury followed by liver, pancreas and kidney. Among the splenic injury patients, major proportion were grade III and grade IV injuries. The percentage of grade II and grade III injuries were higher among liver injury patients. The percentage of grade III injury was greater among patients with pancreatic injury compared to Grades II and IV. Among the study population 82.14 % had flat IVC, 93.3% had hypotension and 76.7% had both hypotension and flat IVC. The proportion of the subjects with flat IVC was highest among splenic injury subjects. The proportion of subjects with hypotension was highest and similar among splenic and liver injury patients. The combination of flat IVC and hypotension was also highest among subjects with splenic injury. Flat IVC had a sensitivity of 82.14% (95% CI 63.11% to 93.94%) and a specificity of 100.00% (95 CI 15.81% to 100%).The positive and negative predictive values were 100% and 28.57% respectively. Hence, flat IVC on CT could be of value in predicting hypotension among blunt abdominal trauma patients. Perhaps, this finding could serve the treating physician as an aid in early diagnosis and management to prevent mortality in such patients.

LIMITATIONS AND RECOMMENDATION

As the study was a cross-sectional study, the follow up of the patients was limited due to the study design. Due to the small sample size, the external validity of the present study limits the generalization of the study findings and hence, further large longitudinal cohort studies are required to validate our findings.

The primary health care centres in India are deficient in sophisticated diagnostic aids, especially CT scan. Hence, the value of flat IVC cannot be assessed in such situations.

SUMMARY

People who encounter road accidents often have blunt type of abdominal injury. The victims of road accident are often brought to the emergency room in a hemodynamically stable condition. But their condition can deteriorate later after admission. The vital signs are often used to assess the stability in such conditions but have less accuracy in predicting the severity of hemodynamic status. The IVC diameter assessment through CT scan can be relied on in such conditions to determine the hemodynamic status. Hence the present study was aimed to assess the diameter of IVC on CT and to use its ratio in predicting hypotension among the blunt abdominal trauma patients.

This study included 30 subjects with a history of blunt abdominal injury with a mean age of 26.93 ± 11.51 years for analysis. Majority of subjects were in the age group of 21 to 40 years. There was a significant male preponderance 83.3% of the study subjects were men. All the 30 patients had involvement of the solid organs, among whom 16(53.3%) had splenic injury, 15(50%) had liver injury, 4(13.3%) had pancreatic injury and 5(16.7%) had kidney injury. Among the study population, 90% had hemoperitoneum. Among the splenic injury patients, major proportion were grade III (37.5%) and grade IV (37.5%) injuries. The percentage of Grade II and Grade III (n=5, 33.33% each) injuries were higher among liver injury patients. The percentage of grade III (n=2,50%) injury was greater among patients with pancreatic injury compared to grades II and IV (n=1, 25% each). Whereas, the percentage of grade I and III (n=2, 40% each) injuries was equal among patients with kidney involvement.

Among the study population 23(76.7%) had flat IVC and 7 had non-flat IVC. Among the study population, 28(93.3%) had hypotension. Among the study population 23(76.7%) had both hypotension and flat IVC. The proportion of the subjects with flat IVC was highest among those with splenic injury. The proportion of subjects with hypotension was highest and similar among splenic and liver injury patients. The combination of flat IVC and hypotension was also highest among subjects with splenic injury.

Flat IVC had sensitivity of 82.14% (95% CI 63.11% to 93.94%), specificity of 100.00% (95 CI 15.81% to 100%) in detecting hypotension. The positive predictive value was 100.00% (95 CI 85.18% to 100%), negative predictive value was 28.57% (95 CI 3.67% to 70.96%), and the total diagnostic accuracy was 83.33% (95 CI 65.28% to 94.36%).

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ANNEXURE I - INFORMED CONSENT

TITLE OF THE STUDY: "VENOUS PHASE DIAMETER OF INFERIOR VENACAVA ON COMPUTED TOMOGRAPHY- A PREDICTOR OF HYPOTENSION IN BLUNT ABDOMINAL TRAUMA -ONE YEAR HOSPITAL BASED OBSERVATIONAL STUDY"

PRINCIPAL INVESTIGATOR:

INTRODUCTION AND PURPOSE: Blunt abdominal trauma have become very common due to increased road traffic accidents in recent years. Blunt abdominal trauma is associated with rapid volume loss with multiple organ injuries sometimes with negligible clinical signs.

Furthermore, the diagnostic accuracy of physical examination in abdominal visceral injury is low.

Due to the non-specific symptoms and lack of reliable diagnostics for identifying hypovolemia and haemorrhagic shock, additional parameters are required with improved sensitivity and specificity to diagnose hypovolemic shock. Thus, imaging is a fundamental tool for triage and diagnosis.

This calls for a rapid, reliable, reproducible and cost-effective imaging modality.

Contrast enhanced computed tomography is a rapid technique for accurate estimation and early diagnosis of organ injuries as well as their grades, presence of even minimal amount of hemoperitoneum, altered IVC diameter and thus helping in predicting volume depletion, for monitoring its adverse consequences thus helping in faster initiation of treatment and reducing preventable mortality.

PROCEDURE: I request you to kindly participate in the study titled "Venous phase diameter of inferior venacava on computed tomography - a predictor of hypotension in blunt abdominal trauma-one year hospital based observational study" If you agree to participate in the study please furnish the details pertaining to the study

The scanning equipment to be used is siemens somatom 64 slice computed tomography scanner. CT scan of the abdomen is performed with patient in supine position and then the images are reconstructed into different planes. The diameter of the IVC and associated solid organ injuries are studied in detail.

BENEFITS: Results will help in early diagnosis of hypotension and associated solid organ injuries if any in blunt abdominal trauma patients and hence allows for early and better treatment plan.

RISKS:

1. Radiation hazard
2. Contrast reaction

ALTERNATIVES: If patient is not willing to take part in the study, his / her treatment or any other further investigations the patient wants to undergo, in future, in KLE will not be affected by his / her decision.

VOLUNTARY PARTICIPATION/WITHDRAWAL: Taking part in this study is voluntary. I may choose not to take part in this study, or if I decide to take part, I can later change my mind and withdraw from the study. My decision will not change the present or future health care or other services that I receive. The study doctor or the sponsor may stop my participation in this study. I will tell of any important new findings that may change my willingness to continue to take part. If I choose not to take part in the study, I will receive the standard treatment for patients with my condition.

COSTS: NIL. (The study is to be conducted on the participants who are advised CT abdomen as an investigation for blunt abdominal trauma by the referring consultant and the participants will bear the charges for it.)

PAYMENT FOR PARTICIPATION: No incentive will be paid to you for participating in this study.

COMPENSATION: In the event that I become injured as a result of taking part in this study, treatment will be offered to me, no reimbursement, compensation or free medical care is given.

CONFIDENTIALITY: All information collected about me during the course of the study will be kept confidential to the extent permitted by the law. The code numbers will identify me in this research record. Information from this study may be published but my identity will be confidential in any publication.

QUESTION: If any enquiries in the future or in case of research related injury illness, you may contact following person.

Dr. Roopa Bellad
Professor of Paediatrics Chairperson, J.N. Medical College Institutional Ethical Committee for Human Subjects Research, Belagavi
Ph. 0831-2471525 Ext- 4032

CONSENT TO PARTICIPATE IN RESEARCH STUDY:

1. I understand that I am participating in the study, which includes CT scan of the abdomen and pelvis
2. I confirm that I have read and understood the information in the patient information sheet. Procedure is explained to me in detail along with information about the advantages and disadvantages of taking part in the study. I have been given the opportunity to discuss all aspects of the trial, to ask questions and hereby consent to participation in the trial outlined above.
3. I understand that the decision to take part in this study is completely voluntary and I am aware that I can choose to withdraw from the study at any point of time.
4. I consent to the photographing or recording of the procedure to be performed including portions of my body, for medical, scientific or educational purposes provided my identity is not revealed in the pictures or by the descriptive texts accompanying them.
5. I understand that there is no significant risk involved in the test that would be done in this study.
6. No guarantee or assurance has given by anyone as to the results that may be obtained.
7. My signature on this form signifies that I have willingly decided to participate after understanding the above information.

Signature /Left thumb print of the participant or legally authorized representative.

Participant's Name:………………………………

Signature/ Left thumb impression. : ……………………………...

Name of the legally authorized representative:………………………………

Signature/ Left thumb impression. :………………………………

Witness's Name : ……………………………...

Signature/ Left Thumb impress :……………………………....

Investigators name and Signature : ………………………………

Date:

Place: Belagavi

ANNEXURE II - ETHICAL CLEARANCE LETTER

K.L.E.UNIVERSITY'S

JAWAHARLAL NEHRU MEDICAL COLLEGE,

NEHRU NAGAR, BELAGAVI-590010 (KARNATAKA-INDIA)

(Accredited 'A' Grade by NAAC)

Website: http//www.jnmc.edu
E-Mail : dome@jnmc.edu

Phone: (+ 91-(0)831 Office : 2471350
Principal: 2471701
Fax No. +91 (0)831 – 2470759

Ref: MDC/DOME/ 09

Date: 22/11/2017

To,

PG student in Radiodiagnosis,
J.N.Medical College,
BELAGAVI.

Sub: Institutional Ethical Clearance for the study.

With reference to the above, we wish to inform you that your proposed research project titled **"VENOUS PHASE DIAMETER OF INFERIOR VENACAVA ON CT- A PREDICTOR OF HYPOTENSION IN BLUNT ABDOMINAL TRAUMA – A ONE YEAR OBSERVATIONAL IN KLE'S DR PRABHAKAR KORE'S HOSPITAL AND MRC"**, is ethical and justifiable. The proposed research project has been cleared by the JNMC Institutional Ethics Committee on Human Subjects Research.

(Dr. Arathi Darshan)
Member Secretary
JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N.Medical College, Belagavi.

(Dr. Roopa M Bellad)
Chairman,
JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N.Medical College, Belagavi.

ANNEXURE - III - PROFORMA

DATA COLLECTION INSTRUMENT

VENOUS PHASE DIAMETER OF INFERIOR VENACAVA ON COMPUTED TOMOGRAPHY- A PREDICTOR OF HYPOTENSION IN BLUNT ABDOMINAL TRAUMA -ONE YEAR HOSPITAL BASED OBSERVATIONAL STUDY

PATIENT DATA

SL.NO.		DATE	
PATIENT NAME		CT SCAN NO.	
AGE		SEX	

HISTORY

H/O BLUNT ABDOMINAL INJURY	YES/NO
MECHANISM OF INJURY	RTA/ ASSAULT/FALL
ABDOMINAL PAIN	YES/NO

INVESTIGATIONS

BLOOD PRESSURE (mm Hg)	
USG -ABDOMEN	
CECT ABDOMEN	

CT FINDINGS

HEMOPERITONEUM AND DEGREE	**Y/N**	**MINIMAL**	**MILD**	**MODERATE**
SOLID ORGAN INJURY		**GRADING (I/II/III/IV)**		
LIVER INJURY	**Y/N**			
SPLENIC INJURY	Y/N			
PANCREATIC INJURY	Y/N			
RENAL INJURY	Y/N			
BLADDER INJURY	Y/N			
IVC- ANTEROPOSTERIOR (AP) DIAMETER				
IVC – TRANSVERSE (T) DIAMETER				
IVC- T: AP RATIO				

HEMOTHORAX		
PNEUMOTHORAX		
FRACTURE	VERTEBRA	
	RIBS	
	PELVIS	
DIAPHRAGM INJURY		

ANNEXURE – IV - CLINICAL IMAGES

CASE 1. A 20-year-old female presented with a history of blunt abdominal trauma in RTA. She underwent CT scan of the abdomen for the same which revealed subcapsular non-enhancing hypodense area along the lateral margin indenting on the adjacent liver parenchyma. Spleen shows multiple patchy non-enhancing areas involving the entire parenchyma reaching up to the hilum. Mild hemoperitoneum noted. Rib fractures involving the left 7^{th}, 8^{th}, 9^{th} and 10^{th} ribs noted.

Image 1a: Axial CT image showing grade IV splenic and grade II liver injury

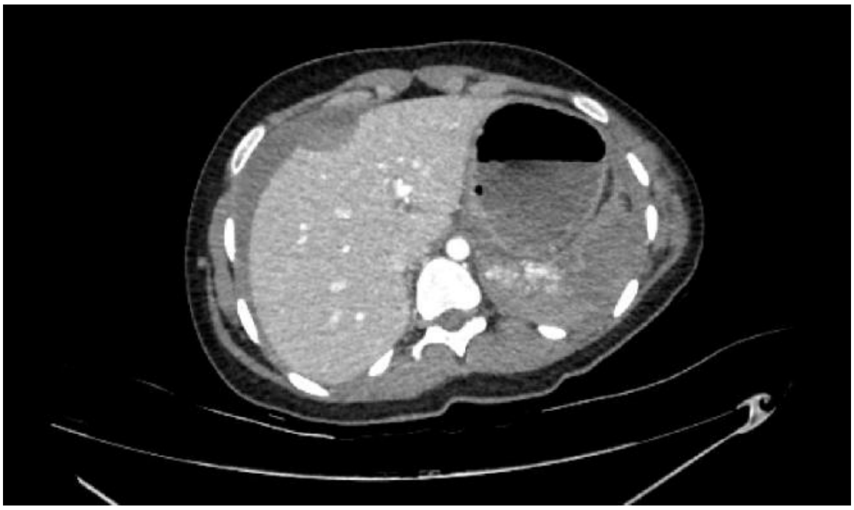


Image 1b: Axial CT image grade IV splenic injury

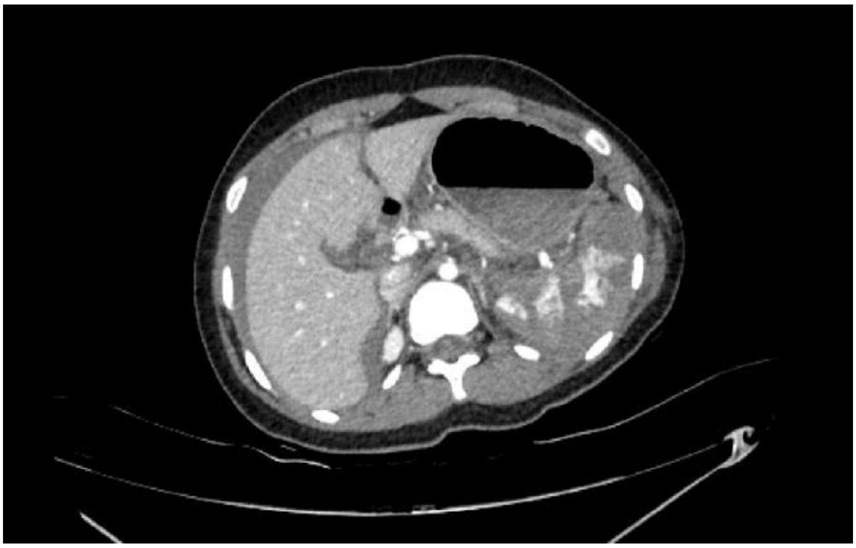


Image 1c: Sagittal CT image showing grade II liver injury

Image 1d: Coronal CT image grade IV splenic injury

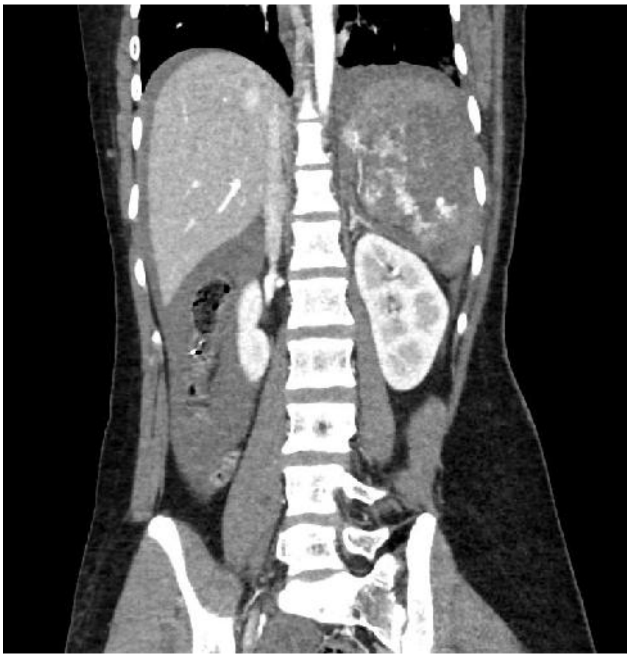


Image 1e: Coronal CT image showing mild hemoperitoneum

Image 1f: Volume rendering technique showing rib fractures on left side

Image 1g: Axial CT showing flat IVC in the same patient.

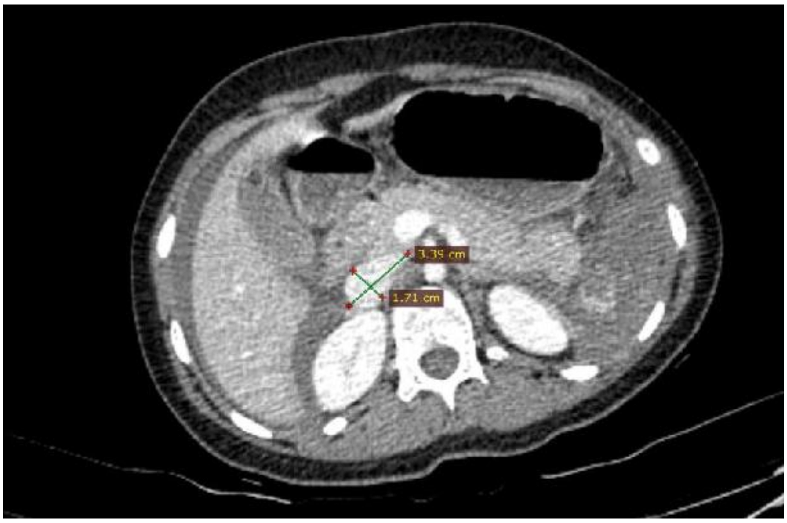


Table 1- patient 1

ORGAN INJURY AND AAST GRADE		GRADEOF HEMOPERITONEUM	IVC RATIO (TRANSVERSE: ANTEROPOSTERIOR)
Spleen	IV		
Liver	III	mild	2.0
Pancreatic			
Renal			

CASE 2. A 32-year-old male presented with a history of blunt abdominal trauma in a RTA. He underwent CT scan of the abdomen which revealed ill-defined non enhancing hypodense areas in the segment 7 and 8 of liver. There is moderate degree hemoperitoneum.

Image 2a: Axial CT image showing grade IV liver injury

Image 2b: Axial CT image showing grade IV liver injury.

Image 2c: Axial CT image showing moderate degree free fluid with HU+65 suggestive of hemoperitoneum.

Image 2d: Coronal CT image showing grade IV liver injury.

Image 2e: Sagittal CT image showing grade IV liver injury.

Image 2f: Axial CT image showing flat IVC in the same patient.

ORGAN INJURY AND GRADE		GRADEOF HEMOPERITONEUM	IVC RATIO (TRANSVERSE: ANTEROPOSTERIOR)
		moderate	2.24
Spleen			
Liver	IV		
Pancreatic			
Renal			

Case 3. A 9-year-old male presented with a history of blunt abdominal trauma in RTA. He underwent CT scan of the abdomen which revealed non-enhancing hypodense area involving the segment 5 of right lobe of liver with a thin rim of sub capsular hematoma along the right anterolateral aspect. Spleen showed ill-defined non-enhancing hypodense areas along the upper pole extending from the capsular region to the hilum.

Image 3a: Axial CT scan showing AAST grade III splenic injury

Image 3b: Axial CT image showing AAST grade I liver and grade III splenic injury

Image 3c: Axial CT image showing AAST grade III splenic injury

Image 3d: Coronal CT image showing AAST grade III splenic injury

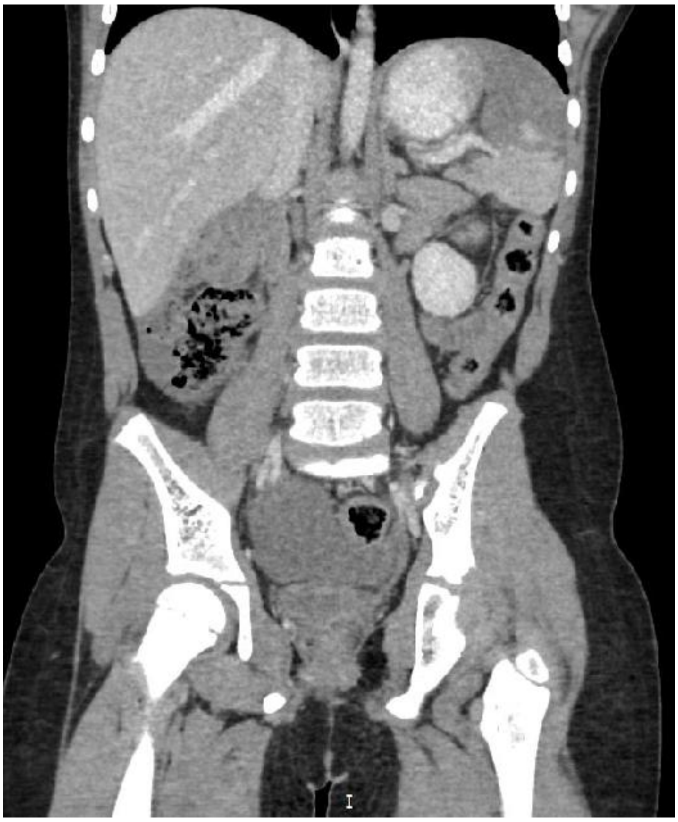


Image 3e: Sagittal CT image showing AAST grade III splenic injury

Image 3f: Axial CT image showing flat IVC in the same patient

ORGAN INJURY AND AAST GRADE		GRADEOF HEMOPERITONEUM	IVC RATIO (TRANSVERSE: ANTEROPOSTERIOR)
Spleen	III		
Liver	I	Mild	2.2
Pancreatic			
Renal			

Case 4. A 30-year-old female presented with a history of blunt abdominal trauma in a RTA. She underwent CT scan of the abdomen which revealed non-enhancing hypodense areas extensively involving both the poles extending up to the hilum suggestive of laceration. Large subcapsular and intraparenchymal splenic hematoma noted. Minimal hemoperitoneum noted.

Image 4a: Axial CT image showing AAST grade IV splenic injury.

Image 4b: Axial CT image showing AAST grade IV splenic injury.

Image 4c: Axial CT image showing AAST grade IV splenic injury.

Image 4d: Axial CT image showing minimal free fluid in the pelvis with HU+64 suggestive of hemoperitoneum

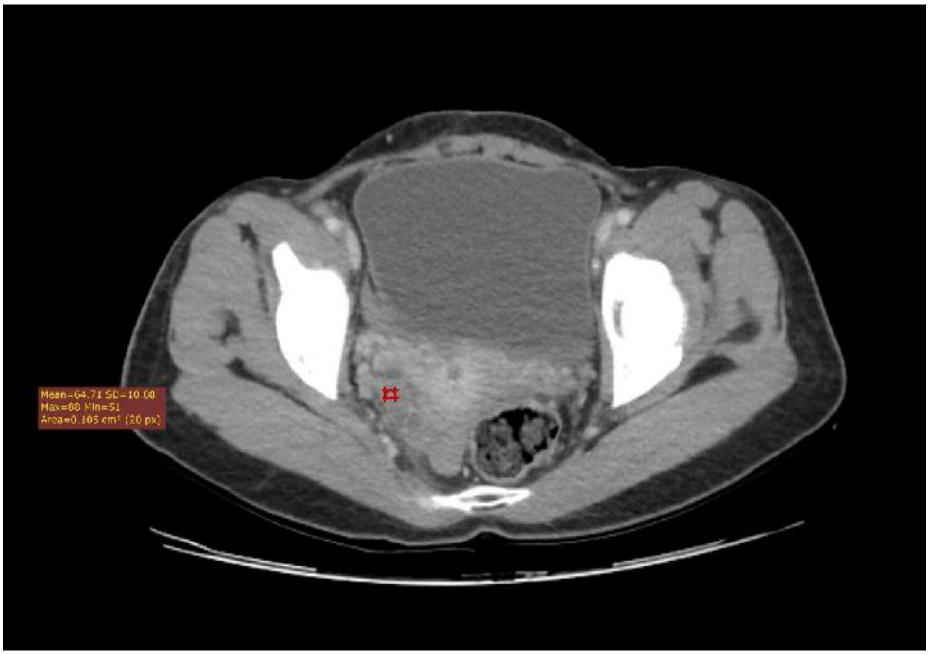
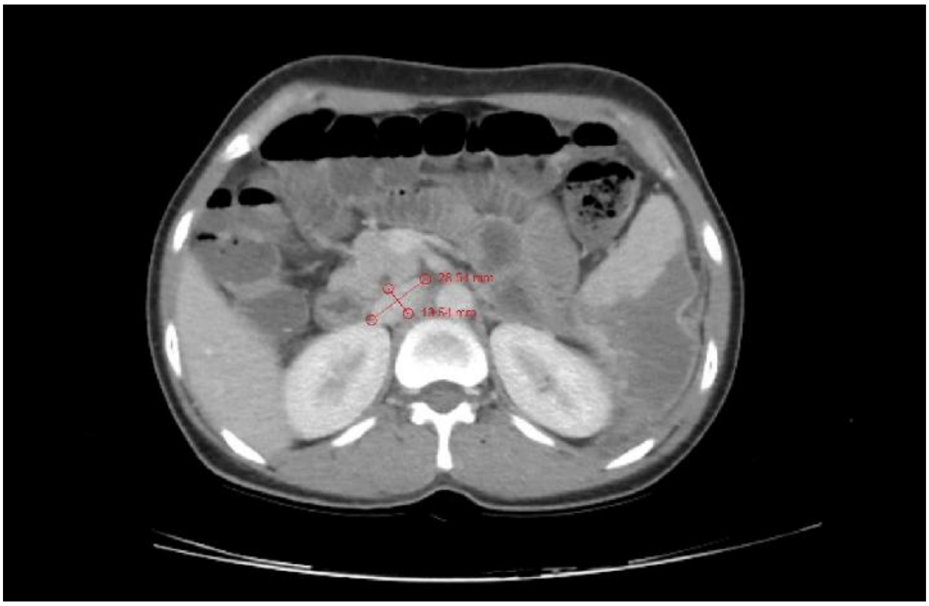


Image 4e: Axial CT image showing flat IVC in the same patient.



ORGAN INJURY AND AAST GRADE		GRADEOF HEMOPERITONEUM	IVC RATIO (TRANSVERSE: ANTEROPOSTERIOR)
		minimal	2.11
Spleen	IV		
Liver			
Pancreatic			
Renal			

Case5. A 25-year-old male with a history of blunt abdominal trauma due to RTA. He underwent CT scan of the abdomen which revealed a linear hypodense area with air pockets involving right lobe of the liver (segment VII & VIII). The tract is seen to end in an ill-defined hypodense area suggestive of laceration. There is evidence of fracture of right 6th and 7th ribs.

Image 5a: Axial CT image showing AAST grade III liver injury.

Image 5b: Axial CT image showing AAST grade III liver injury.

Image 5c: Coronal CT image showing AAST grade III liver injury.

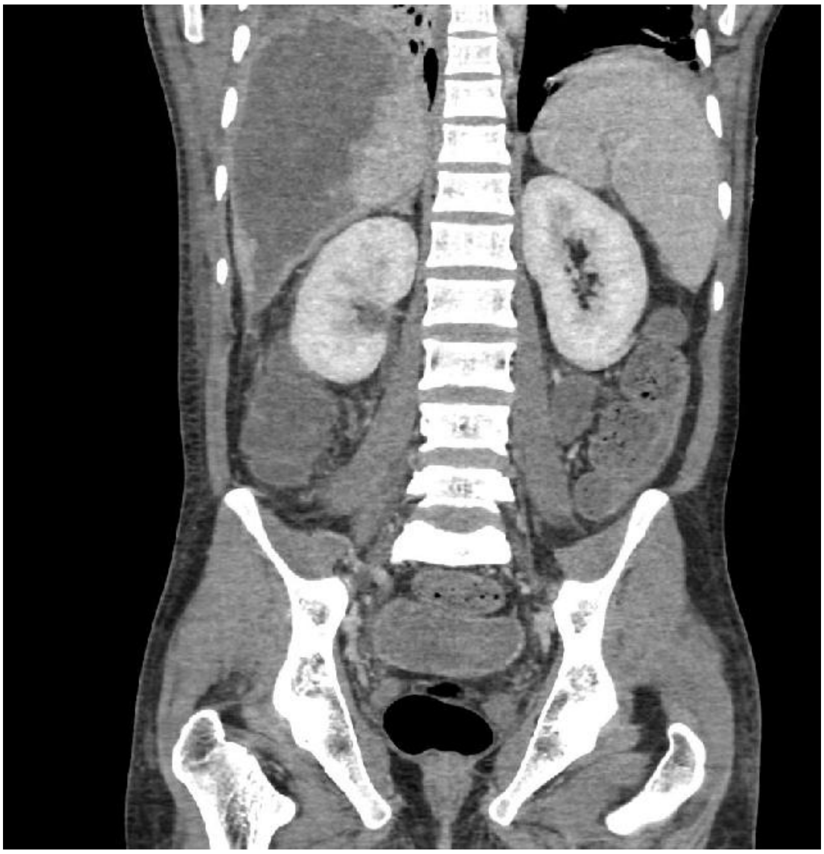


Image 5d: Coronal CT image showing moderate degree free fluid.

Image 5e: Sagittal CT image showing AAST grade III liver injury.

Image 5f: Axial CT image showing flat IVC in the same patient.

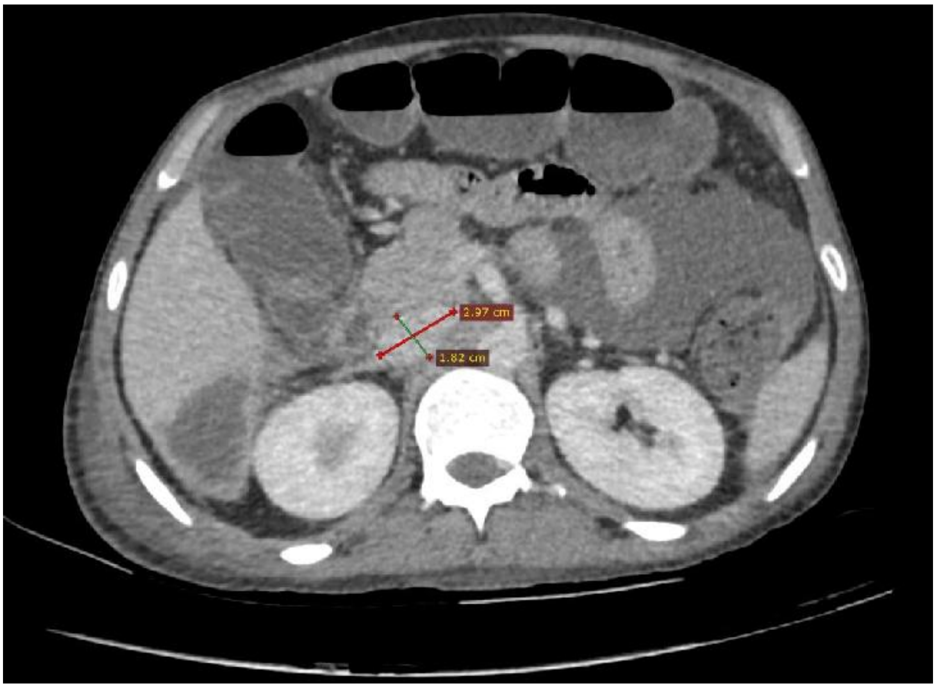
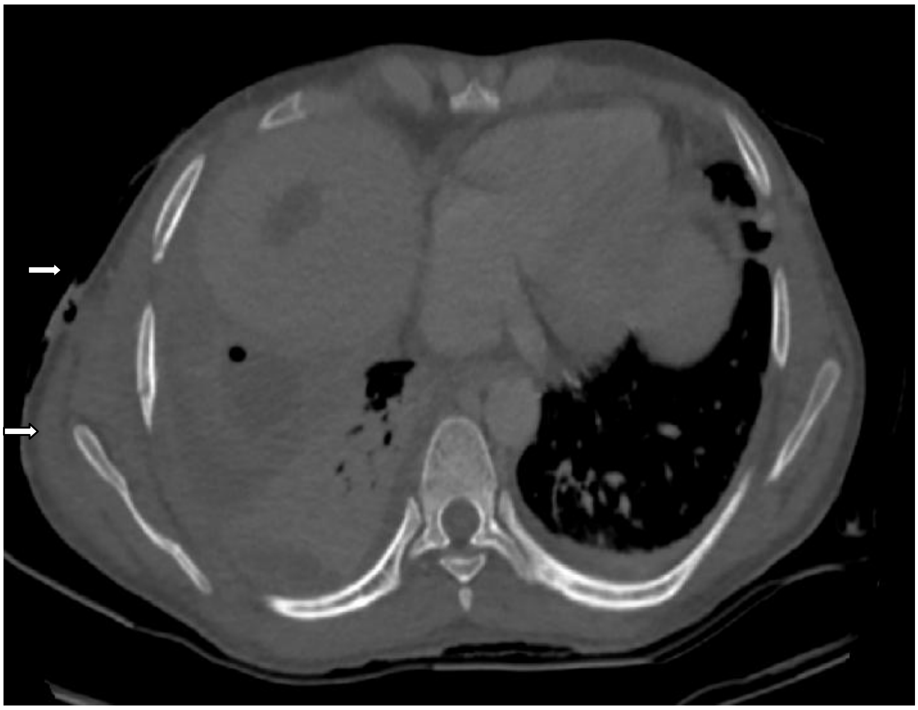


Image 5f: Axial CT image- bone window showing fracture of right showing fracture of right 6thand 7thribs.



ORGAN INJURY AND GRADE		GRADEOF HEMOPERITONEUM	IVC RATIO (TRANSVERSE: ANTEROPOSTERIOR)
		moderate	1.6
Spleen			
Liver	III		
Pancreatic			
Renal			

Case 6. 5year old male with a history of blunt abdominal trauma due to RTA. He underwent CT scan of the abdomen which revealed a hypodense area in the segment 5 of liver, suggestive of contusion. Pancreas appears bulky with non-enhancing hypodense area in the body suggestive of laceration. Right kidney appears heterogenous and shows non-opacification of contrast with hypodense subcapsular collection.

Image 6a: Axial CT image showing AAST grade IV renal and grade III pancreatic injury

Image 6b: Axial CT image showing AAST grade IV right renal and grade III pancreatic injury

Image 6c: Axial CT image showing hypodense area in the segment 5 of liver suggestive contusion (AAST grade I)

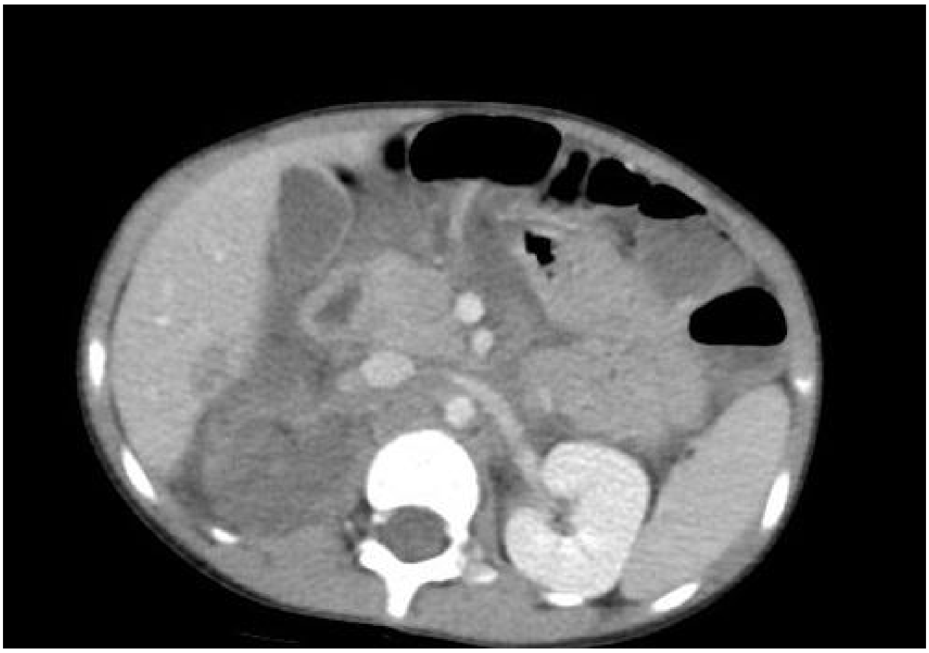
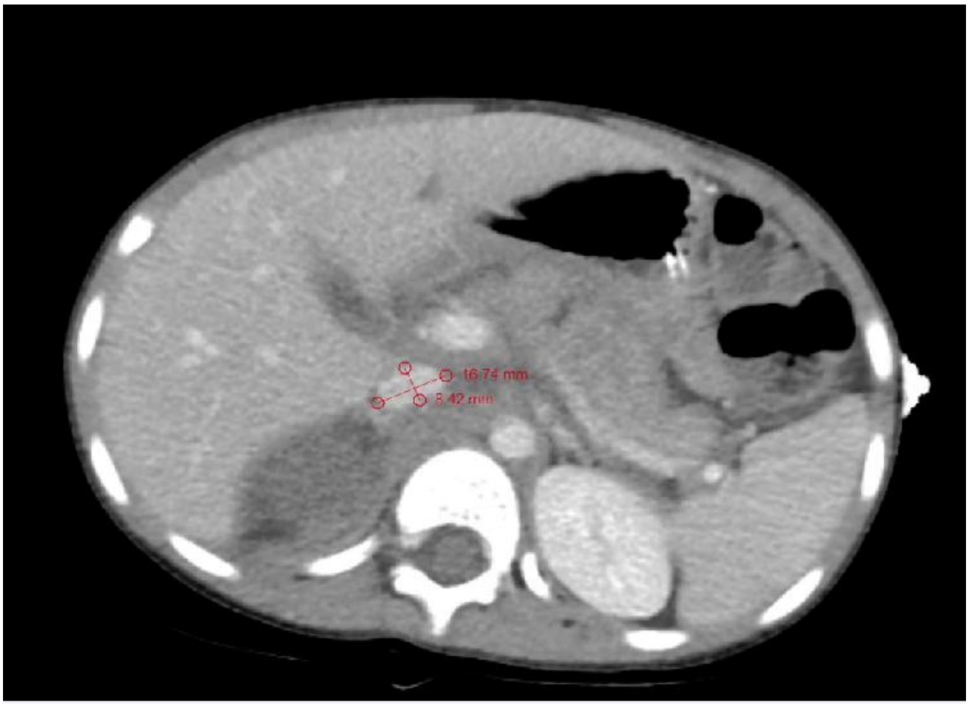


Image 6d: Axial CT image showing AAST grade IV right renal injury

Image 6d: Axial CT image showing flat IVC in the same patient



ORGAN INJURY AND AAST GRADE		GRADEOF HEMOPERITONEUM	IVC RATIO (TRANSVERSE: ANTEROPOSTERIOR)
Spleen	III		
Liver	I	mild	1.98
Pancreatic			
Renal	IV		

Case 7. A 21year old male with a history of blunt abdominal trauma due to RTA. He underwent CT scan of the abdomen which revealed ill-defined non enhancing hypodense area in the head and uncinate process of pancreas suggestive of pancreatic laceration. There is a well-defined mixed density hematoma (HU +60 to +70) inferior to the head and uncinate process of pancreas. Moderate degree free fluid of HU +63 suggestive of hemoperitoneum.

Image 7a: Axial CECT- showing AAST grade IV pancreatic injury

Image 7b: Axial CECT- showing AAST grade IV pancreatic injury

Image 7c: Coronal CT image showing AAST grade IV pancreatic injury

Image 7d: Coronal CT image showing hematoma inferior to the pancreas

Image 7e: Axial CT image- showing hemoperitoneum

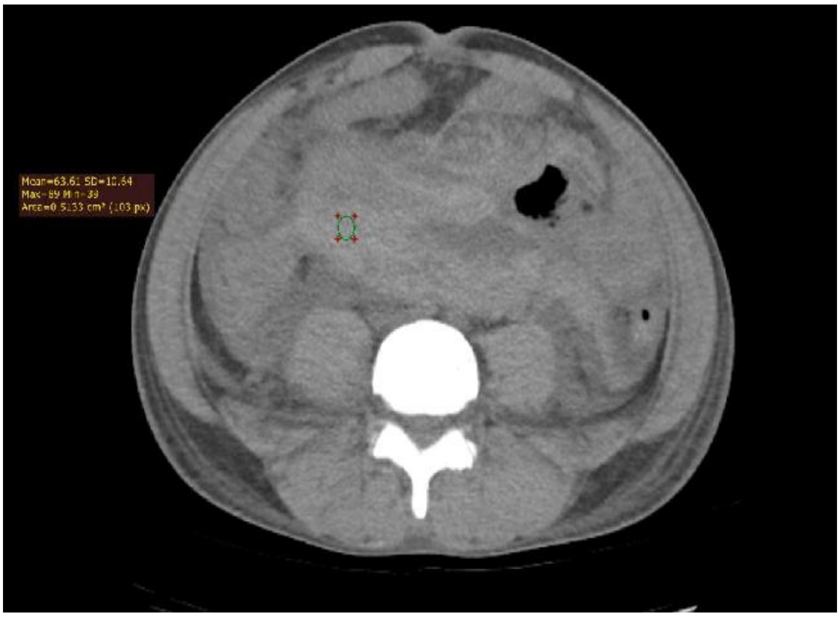


Image 7f: Axial CT image- showing flat IVC in the same patient

ORGAN INJURY AND AAST GRADE		GRADEOF HEMOPERITONEUM	IVC RATIO (TRANSVERSE: ANTEROPOSTERIOR)
Spleen			
Liver			
Pancreatic	IV		
Renal			

Sl no.	CT No.	Age (in years)	Sex	Blunt Abdominal Trauma	Mechanism of injury	Hemoperitoneum	Solid Organ Involvement	Organ Injury With AAST grade						
								Spleen	Liver	Pancreas	Right kidney	Left kidney	hemothorax	Others
1	44062	21	M	present	RTA	Minimal	Yes	grade iv	grade iii	no	no	no	No	No
2	46014	20	M	present	RTA	Mild	Yes	grade iv	no	no	no	no	No	No
3	49059	40	M	present	RTA	Mild	Yes	no	grade i	no	no	no	No	No
4	52124	32	M	present	RTA	Moderate	Yes	no	grade iv	no	no	no	No	No
5	53834	31	M	present	RTA	N	Yes	grade ii	no	no	no	no	No	No
6	56301	28	M	present	RTA	Minimal	Yes	no	grade i	no	no	no	No	Ribs fracture
7	56548	28	M	present	RTA	moderate	Yes	grade ii	grade ii	no	no	grade i	No	Mesenteric tear
8	584	9	M	present	RTA	Mild	Yes	grade iii	grade i	no	no	no	No	No
9	765	23	M	present	RTA	Mild	Yes	grade i	no	no	no	grade i	No	Diaphragm rupture
10	1440	16	M	present	FALL	Minimal	Yes	grade iv	no	no	no	no	No	No
11	1856	65	M	present	RTA	Minimal	Yes	grade iii	no	no	no	no	hemothorax	Ribs fracture
12	1916	41	F	present	RTA	Moderate	Yes	grade ii	no	no	no	no	No	Pelvic fracture
13	2449	21	M	present	RTA	Moderate	Yes	no	no	grade iv	no	no	No	Vascular injury
14	3032	26	M	present	RTA	Mild	Yes	grade iv	no	no	no	no	No	Ribs fracture
15	3353	30	F	present	RTA	Minimal	Yes	grade iv	no	no	no	no	No	No
16	3601	38	M	present	RTA	N	Yes	grade iii	grade iii	no	no	no	No	No
17	3726	5	M	present	RTA	Mild	Yes	no	grade i	grade iii	grade iv	no	No	No
18	3893	24	M	present	RTA	Mild	Yes	no	grade iii	no	no	no	No	No
19	4131	28	F	present	RTA	Mild	Yes	no	grade ii	no	no	no	No	No
20	4286	9	M	present	RTA	Moderate	Yes	grade iii	no	no	no	no	No	Pneumothorax
21	4547	25	M	present	RTA	N	Yes	no	grade iii	no	no	no	No	
22	5141	25	M	present	RTA	Mild	Yes	no	no	grade ii	no	no	No	No
23	5950	20	M	present	RTA	Minimal	Yes	no	no	no	no	grade iii	No	No
24	6573	28	M	present	RTA	Moderate	Yes	grade iii	no	no	no	no	No	Hemo-pneuomothorax
25	6868	40	M	present	RTA	Mild	Yes	no	no	grade iii	no	no	No	No
26	6976	13	M	present	RTA	Moderate	Yes	grade iii	no	no	no	no	No	No
27	7351	20	F	present	RTA	Mild	Yes	grade iv	grade ii	no	no	no	No	No
28	7391	25	M	present	RTA	Moderate	Yes	no	grade iii	no	no	no	No	Ribs fracture
29	7510	29	M	present	RTA	minimal	Yes	no	grade ii	no	no	no	No	Ribs fracture
30	8607	37	F	present	RTA	Minimal	Yes	no	grade ii	no	grade iii	no	No	Vertebral fracture

Sl no.	Combination	Systolic BP	Diastolic BP	Presence of hypotension	IVC diameter (AP) cms	IVC diameter (transverse)cm	IVC diameter (transverse:AP) ratio	Flat ivc (FIVC)
1	Splenic +Liver	88	60	Yes	1.3	3	2.31	Present
2	Splenic alone	82	60	Yes	0.8	2.36	2.9	Present
3	Liver alone	88	60	Yes	1.14	2.37	2.08	Present
4	Liver alone	84	60	Yes	1.35	3.1	2.29	Present
5	Splenic alone	88	60	Yes	1.4	2.5	1.79	Absent
6	Liver alone	86	58	Yes	0.8	1.9	2.37	Present
7	Kidney + Splenic +Liver	80	60	Yes	1.09	2.7	2.48	Present
8	Splenic +Liver	80	62	Yes	1	2.2	2.2	Present
9	Splenic + Kidney	114	96	No	1.7	2.9	1.7	Absent
10	Splenic alone	86	58	Yes	1.5	3.4	2.26	Present
11	Splenic alone	88	58	Yes	1.47	3.4	2.31	Present
12	Splenic alone	86	60	Yes	1.87	2.92	1.56	Present
13	Pancreatic alone	80	58	Yes	0.72	2.54	3.49	Present
14	Splenic alone	88	58	Yes	1.23	2.44	1.98	Present
15	Splenic alone	86	64	Yes	0.95	2.53	2.66	Present
16	Splenic +Liver	84	66	Yes	1.55	3.42	2.26	Present
17	Pancreatic +Kidney +Liver	80	50	Yes	0.8	1.76	2.2	Present
18	Liver alone	88	56	Yes	1.38	2.68	1.94	Present
19	Liver alone	86	56	Yes	0.81	2.26	2.79	Present
20	Splenic alone	88	60	Yes	0.87	1.85	2.12	Present
21	Liver alone	88	64	Yes	1.375	2.72	1.98	Present
22	Pancreatic alone	88	58	Yes	1.9	3.5	1.84	Absent
23	Kidney alone	80	50	Yes	0.7	2.4	3.4	Present
24	Splenic alone	86	58	Yes	1	2.39	2.39	Present
25	Pancreatic alone	88	60	Yes	1.26	2.9	2.3	Present
26	Splenic alone	88	60	Yes	1.4	2.7	1.92	Present
27	Splenic +Liver	88	60	Yes	1.72	3.49	2	Present
28	Liver alone	86	60	Yes	1.45	2.46	1.69	Absent
29	Liver alone	110	80	No	1.7	2.8	1.64	Absent
30	Liver + Kidney	88	58	Yes	1.9	2.5	1.31	Absent