










# Inferior vena cava injuries: Are we doing what we really must?

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## ABSTRACT

**Objective:** The inferior vena cava (IVC) is one of the most frequent injured intra-abdominal vessels and its treatment requires prompt action. Despite advances in reanimation in last decades, there has not been proportional improvement in IVC mortality. This report aims to discuss the mortality predictive factors including the adherence to balanced reanimation and damage control surgery (DCS) in daily trauma assistance, their repercussions on outcomes, comparing our institution outcomes to literature.

**Material and Methods:** A retrospective design analysis was made through database records of trauma patients at Clinic Hospital of University of Campinas, UNICAMP in order to investigate patients with IVC injuries, putting an emphasis on mortality predictive factors.

**Results:** Seventy-four patients were identified with IVC injury from January 1990 to August 2017. Predominant mechanism was penetrating with 87.8% (76.3% gunshot). On arrival, 37.8% of all of the victims were hypotensive, and ISS median was 24.5. Regarding location of IVC, 68.5% were infrarenal, 12.2% were suprarenal, 18.9% retrohepatic. Simple repair was performed in 60.8%. Ligation was carried out in 27% and atriocaval shunt was performed in 4.1%. There was not enough time for specific procedure in 8.1%. Associated intra-abdominal injuries were present in 97.3%, and the mean of transfusional requirements was  $9.1 \pm 6.9$  for packed red blood cells. Overall mortality rate was 52.7%, with a mortality rate for infrarenal injuries being 39.2%. Damage control surgery was adopted in 33.8%, with 68% mortality.

**Conclusion:** A solid comprehension of shock reanimation has progressively been disseminated; however, trauma care professionals must assure that they are being applied with balanced reanimation and DCS.

**Keywords:** Abdominal vascular injury, damage control, inferior vena cava, ligation, mortality, hypovolemic shock

## INTRODUCTION

Hemorrhagic shock is the most common immediate cause of death in trauma and requires immediate and coordinate action to be reversed (1,2). In the last decade, new concepts have been created in order to avoid the lethal triad of hypothermia, acidosis, and coagulopathy. Resuscitative strategies have also evolved to include principles such as permissive hypotension, minimizing the use of crystalloid before surgical control of bleeding, and blood infusion through massive transfusion protocol (3). Moreover, the constant progress on pre-hospital care, surgical technique damage control surgery (DCS) and critical care have determined a better prognosis for trauma patients (3-5).

Inferior vena cava (IVC) injuries, due to their potential for significant bleeding, play an important role, according to the literature, accounting for up to 40% of all major intra-abdominal vascular injuries (6-11).

Surgical approach for bleeding control is crucial, hence an objective and thorough evaluation of the patient's clinical condition, associated visceral injuries, complexity of vascular injury and the identification of the involved IVC segment is central to determine surgical strategy.

Historically, there has been a significant improvement in survival of patients with IVC injuries, as advances in the trauma care have been implemented, evolving from almost 100% to 34-57% mortality rate in midst 1970 (12,13). Despite the continuous and ongoing progress in trauma care, the decrease in mortality rate of such patients is no longer evident; on the contrary, recent manuscripts have reported rates of up to 66% (5). Therefore, identifying mortality predictive factors of such patients has been a priority and some elements have been pointed out including

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- a) clinical status at admission,
- b) amount of blood transfusion,
- c) IVC segment involved, and
- d) surgical repair technique (7,14,15).

Moreover, the impact of those resuscitative strategies in advanced trauma support has not yet been consistently measured as a factor influencing mortality in patients with IVC injury, specifically. The development and implementation of these conducts have been gradual and have required continuous multispecialty training before being fully implemented as a routine in trauma assistance (16).

The aim of the present study was to describe the experience of an academic level one trauma referral center on IVC injuries with emphasis on mortality predictive factors, rates and compare our institution outcomes to scientific literature. Moreover, the present manuscript seeks to discuss adherence to current principles in trauma assistance and their repercussions on outcomes.

#### MATERIAL and METHODS

After approval of the committee of research ethics and institutional review board of University of Campinas (School of Medical Sciences, Unicamp - number 887.154) we conducted a retrospective review of all traumatic IVC injuries between January 1990 and August 2017. Data were harvested from the database of the Division of Trauma Surgery (DTS) at Clinic Hospital of University of Campinas. This hospital is a level one trauma center with about 500 beds, and it is the referral center for 20 cities, encompassing around of 3.5 million people from the public health system.

Patients under 14 years old, who were assisted by the paediatric department and those with iatrogenic IVC injuries and/or injuries secondary to other mechanisms than trauma were excluded from the analysis.

Charts from all patients with IVC injuries were retrospectively analyzed, and information on demographic data, trauma mechanism, emergency medical system (EMS) transport and vital signs at admittance-heart rate (HR), systolic blood pressure (SBP), respiratory rate (RR) and Glasgow coma scale (GCS) were gathered. Moreover, intra-operative findings were also evaluated with emphasis on

- a) IVC injury location,
- b) type of IVC surgical treatment,
- c) need of damage control implementation,
- d) associated intra-abdominal organ injuries,
- e) blood transfusion (number of packed red blood cells in the first 24 hours),
- f) length of stay, and

- g) outcomes (including death and complications).

Trauma scores were calculated using the revised trauma score (RTS), injury severity score (ISS) and trauma injury severity score (TRISS). All trauma victims were conducted according to systematic and institutional protocols, such as ATLS® guidelines, and all diagnosis of IVC injury were made during surgical exploration.

Statistical analysis was done with Microsoft excel (version 16.58). Data associated with mortality rate were assessed by univariate analysis. The other, above mentioned, variables were evaluated with multivariate regression analysis model to determine independent predictors of mortality. A  $p < 0.05$  was considered statistically significant.

#### RESULTS

##### Epidemiological Analysis

Seventy-four patients were identified with IVC lesion; 93.2% (69) were males, with a mean age of  $29.4 \pm 10.2$  years. The mechanism of IVC injury was gunshot wound (GSW) in 53 patients (71.6%), stab wound (SW) in 12 (16.2%), and blunt injury in 9 (12.2%). Fifty percent of the patients were transported by EMS and, on arrival, 37.8% (28) of all of the victims had SBP below 90 mmHg, with a mean overall of  $86.9 \pm 41.6$  mmHg.

Median GCS of the patients was 15, and RTS mean was  $6.5 (\pm 2.1)$ , abdominal trauma index (ATI) mean was  $32.8 (\pm 14.2)$ , and median ISS was 25.

Regarding location of the IVC injury, 68.9% (51) were infrarenal, 12.2% (9) were suprarenal, 18.9% (14) retrohepatic. There was no suprahepatic injury. Simple surgical repair was performed in 60.8% (45), ligation was done in 27% (20) and atrio-caval shunt as DCS was indicated in 4.1% (3). In 8.1% (6) of the cases, there was not enough time for specific conduct of the injury due to intraoperative patient death.

Associated intra-abdominal injuries were present in 97.3% (72) of the cases, with an average of  $2.3 (\pm 1.4)$  wounded viscera per patient (Table 1).

Damage control surgery was performed with packing in 33.8% (25), and repacking was necessary in 5.4% (4).

Overall complication rate was 80% (59), and in 58.1% (42), the complications were related to severe bleeding (Table 2). Mean of transfusional requirements expressed in packed red blood cells was  $9.1 (\pm 6.9)$ , and only 5.4% of patients (4) did not demand any blood transfusion.

Overall mortality rate was 52.7% (39). Of these, 64.1% of the patients (25/39) died in the first 24 hours, and 23.1% (9/39) in the operating room. Mortality in the DCS group was 68% (17/25 patients).

The average length of stay of the patients was  $10.9 (\pm 15.3)$  days, whereas, for patients who were eventually discharged, mean hospital stay was  $16.0 (\pm 11.3)$  days.

**Table 1.** Presence of associated intra-abdominal injuries in the study

Organs	Cases (%)
Liver	35 (47.3%)
Abdominal vessels	31 (41.9%)
Small bowel	25 (33.8%)
Duodenum	23 (31.1%)
Large bowel	20 (27%)
Stomach	18 (24.3%)
Diaphragm	10 (13.5%)
Pancreas	10 (13.5%)
Kidney	6 (8.1%)
Ureter	5 (6.8%)
Mesentery	4 (5.4%)
Gall bladder	4 (5.4%)
Splen	3 (4.1%)
Others	6 (8,1%)

**Table 2.** Number of cases and percentage according to the complications identified

Type of Complication	Cases (%)
Hemorrhagic complication	42 (56.8%)
Infection complication	24 (32.4%)
Renal failure	4 (5.4%)
Acute respiratory distress syndrome	2 (2.7%)
Rhabdomyolysis	1 (1.4%)
Deep vein thrombosis	1 (1.4%)
Pulmonary thromboembolism	1 (1.4%)

**Table 4.** Mortality by operative management and IVC level injury

IVC Segment	Cases	Treatment	Outcome		Mortality by IVC Segment
			Survivors	Non-survivors	
Retrohepatic segment	14 (19%)	Atriocaval shunt	0	3	93% (13)
		Ligation	0	1	
		Suture	1	5	
		EBT	0	4	
Suprarenal segment	9 (12%)	Ligation	0	1	67% (6)
		Suture	3	4	
		EBT	0	1	
Infrarenal segment	51 (69%)	Ligation	7	11	39% (20)
		Suture	24	8	
		EBT	0	1	
Total	74 (100%)	-	35	39	52.7%

EBT: Exsanguination before specific treatment.

**Table 3.** Factors associated with mortality using univariate analysis

Variable	p
EMS	0.0318
GCS	0.0005
SBP < 90 mmHg	0.0010
Blood transfusion	0.0034
ISS	0.0010
TRISS	<0.00010
Injury site	0.0006
Intra-operative bleeding	0.0005 <sup>2</sup>
Type of treatment	0.0020 <sup>3</sup>

Univariate analysis.  
 EMS: Emergency medical system transport, GCS: Glasgow coma scale, SBP: Systolic blood pressure, BD: Blood transfusion, ISS: Injury severity score, TRISS: Trauma injury severity score, Injury site: Anatomical location of IVC injury, Type of treatment: Management of VCI injury.

### Analysis of factors associated with mortality

The application of univariate analysis identified EMS, GCS, SBP, blood transfusion (BD), ISS, TRISS, estimated blood loss, and injury treatment as predictive of mortality (Table 3); and multivariate analysis demonstrated GCS as an independent factor of mortality.

The affected IVC segment also influenced mortality ( $p=0.0006$ ) as shown by univariate analysis. Regression analysis showed retrohepatic segment as the most lethal and the infrarenal is the least (odds ratio retrohepatic vs. infrarenal 20.147/ $p=0.0053$ ).

Mortality comparison between infrarenal and suprarenal segments showed no relevant statistical differences ( $p=0.1381$ ) although suprarenal segment mortality was higher (odds ratio suprarenal vs. infrarenal= 3/ $p=0.1381$ ) (Table 4).

## DISCUSSION

Inferior vena cava injury is still associated with great mortality rate despite significant advances in trauma care. The concepts of balanced hemodynamic resuscitation, damage control surgery and fast physiological recover are the foundation of these advances.

Maciel et al. have reported a relevant series with a 13-year retrospective analysis focusing on the impact of these concepts on patients with IVC injuries. The results did not show different outcomes when compared to the literature. However, this conclusion is limited by the retrospective design of the study, and the analysis period which spanned different practices in the resuscitation of this patient population including the concepts of damage control surgery and hemostatic resuscitation which have only recently become more consolidated (17).

This fact brings attention to our series because, despite an actual well-defined resuscitation protocol, each of our IVC injured patients received assistance from different staff personnel, such as EMS responder, trauma surgeons and anesthesiologist team, possibly resulting in different strategies of reanimation. In addition, due to the long period of the present retrospective analysis, the assistance for IVC injuries provided by the surgical teams along time differed, as the emergence of new concepts in resuscitation protocols have gradually been applied in the surgical emergency routine.

That is why it is important to keep a well-trained multidisciplinary trauma staff to coordinate actions and to make sure all steps of the advanced trauma care are being followed. Training courses on definitive surgical trauma care/definitive anaesthetic trauma care course DSTC/DATC and European trauma course (ETC) have been created for this purpose, and they must be encouraged (18-20).

Several studies have reported overall mortality rate for IVC injuries of 43%, ranging from 21 to 66% (5,14). Klein et al. presented a study with the lowest mortality rate (21%) back in 1990, and they associated their results with a straightforward referral of IVC injured patients in critical state to the operating room (OR), where those patients were put on aggressive fluid resuscitation, mainly with crystalloids. Klein's findings signaled toward better outcomes resulting from the evolution in therapy (15). However, other studies that followed Klein's did not show the same trend (8,14,17,21,22).

Authors of manuscripts that have reported mortality rates above 50%, associate these findings with patients' fast arrival at the hospital, given that 30 to 50% of IVC injured patients die at the scene. The improvements in pre-hospital care and in resuscitation techniques have allowed these patients to get alive to the ER (4,11,21).

In the present study, overall mortality rate was 52.7%, and it did not differ from the literature; however, 64% of the deaths occurred within 24 hour of hospital admittance, which is higher than the 30% demonstrated in the literature (23). In patients with DCS, mortality was 68%, still high, because it was very difficult to identify the moment this approach was adopted.

In this series, the types of surgical correction for IVC injuries were direct repair (suture), ligation, and temporary vascular shunt confection as DCS.

The current literature supports infrarenal IVC ligation in clinically instable patients and in cases with complex IVC lesion as part of damage control concept (16,24). Supra-renal IVC ligation is rarely indicated due to its high mortality rates (25). Sullivan et al. have shown that IVC ligation is more often indicated in patients with clinical instabilities, hypotension, elevated ISS and blood transfusion; and therefore, it is associated with higher mortality rate (11).

Matsumoto et al. have demonstrated, based on a large retrospective analysis of 1.316 IVC injured patients, that IVC ligation was done in 34% of the cases and the mortality rate of these patients in particular was 43.7%. They have concluded that IVC ligation is related to more clinical complications, but mortality rates were not significantly different from those with other types of surgical repair (26).

Byerly et al. have also looked at the impact of IVC ligation on outcomes and concluded that IVC ligation by itself does not predict mortality although it is clearly connected with clinical complications. In their series, IVC ligation was performed in 23.4% of patients, and mortality rate in these patients were 23% (27). It is important to note that both studies did not specify the location of IVC injury neither scrutinized the IVC segment ligated. In our study, 27% of all IVC injuries were treated with IVC ligation, and the associated mortality rate was high with 65%. Two of them were ligations performed in suprarenal portion accounting for 10% of all IVC ligations, and both patients (100%) died on post-operative day one.

Considering only the outcomes of eight infrarenal IVC ligations presented in our study, comprising 90% of all IVC ligations, we reported a mortality rate of 61%, which is higher than previous studies (Table 4,5) (11,28).

It is established that IVC injuries at the infrarenal portion is the least lethal (14,29,30). Therefore, we were expecting a lower overall mortality rate in our study since 69% of the present manuscript IVC injuries were infrarenal, surprisingly it was not the case (Table 6). One of the possible explanations for it is the delay to implement damage control tactics during surgery.

Looking specifically at patients who underwent infrarenal IVC sutures, the present study reported mortality rate of 25% (eight cases), which is also higher than the literature (Table 5) (11,28).

**Table 5.** Comparison of treatment between ligation and suture in patients with IVC injury

<b>A. Comparison without discrimination of IVC level injury</b>						
Study	Number of Patients	Ligation Rate (%)	Ligation Mortality (%)	Suture Rate (%)	Suture Mortality (%)	Overall Mortality
Navsaria (30)	48	62.5%	27.6%	37.5%	36.8%	31%
Huerta (14)	36	33%	-	-	-	56%
Sullivan (11)	100	25%	60%	57%	32.8%	51%
Singer (29)	308	23.4%	45.8%	77%	34.8%	37%
Cudworth (7)	17	37.5%	83.3%	62.50%	16.6%	38%
Van Rooyen (28)	27	14.8%	50%	59.30%	11.8%	37%
Maciel (17)	62	12.9%	75%	50%	33.3%	58%
Matsumoto (26)	1,316	34%	43.6%	66%	36.2%	36%
Byerli (27)	443	23%	23%	76.50%	16%	23%
Goes jr. (24)	114	29.80%	80.60%	70.20%	35.60%	52.60%
Hamptom (23)	35	66%	-	-	-	49%
Present study	74	27%	65%	61%	38%	52.70%
<b>B. Comparison of the infrarenal level group</b>						
Study	Number of Patients with IR Injury n (%)	IR Ligation Rate	IR Ligation Mortality	IR Suture Rate	IR Suture Mortality	IR Mortality
Navsaria	41 (85%)	70%	-	30%	-	23%
Huerta	9 (25%)	55.5%	0	44%	100%	44%
Sullivan	51 (51%)	43%	59%	57%	21%	41%
Singer	-	-	-	-	-	-
Cudworth	4 (25%)	-	-	-	-	25%
Van Rooyen	15 (55.6%)	29%	50%	60%	11%	33%
Maciel	19 (30%)	-	-	-	-	51.70%
Matsumoto	-	-	-	-	-	-
Byerli	-	-	-	-	-	-
Goes jr.	60 (58.3%)	-	-	-	-	63.30%
Hamptom	19 (54%)	89%	-	11%	-	36.80%
Present study	51 (69%)	35%	61%	63%	25%	39%

IVC: Inferior vena cava, IR: Infrarenal.

**Table 6.** Comparison of incidence and mortality by IVC segments-Huerta et al. in 2006 (14)

IVC Level Injury	Average of 30 Years Compiled by Huerta et al.		Present Study	
	Incidence by Segment	Mortality by Segment	Incidence by Segment	Mortality by Segment
Suprahepatic	4%	78%	0%	-
Retrohepatic	19%	69%	19%	93%
Suprarenal*	35%	76%	12%	67%
Infrarenal	39%	23%	69%	39%

\*Suprarenal including the pararenal segment.

Of these eight cases, five of them arrived at the hospital with hemodynamic instability and two of them had associated aortic injury; apparently these are situations that require ligation according to damage control principles (16). Multiple tries to accomplish direct repair may worsen blood loss and result in further clinical instability in an already critical patient. This did not only negatively impact the mortality rates of those patients that eventually had their IVC ligated but also of those who had their IVC repaired.

## CONCLUSION

In conclusion, the present study demonstrated that the theory of advances in trauma care has progressively been disseminated, achieving solid comprehension nowadays. However, trauma care professionals must assure that they are being applied, to decrease the still high overall IVC injury mortality rate. Even when only the infrarenal IVC injuries were considered, mortality rate continued to elevate; and it can be associated with time consuming attempts to repair an injury, deferring damage control and worsening patient's blood loss.

**Ethics Committee Approval:** This study was approved by the committee of research ethics and institutional review board of University of Campinas School of Medical Sciences (Decision no: 887.154, Date: 24.11.2014).

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### ORIJİNAL ÇALIŞMA-ÖZET

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## İnferior vena kava yaralanmaları: Gerçekten yapmamız gerekeni yapıyor muyuz?

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### ÖZET

**Giriş ve Amaç:** İnför vena kava (İVK) en sık yaralanan intra-abdominal damarlardan biridir ve tedavisi hızlı hareket etmeyi gerektirir. Son yıllarda reanimasyondaki ilerlemelere rağmen, İVK mortalitesinde orantılı bir iyileşme olmamıştır. Bu rapor, günlük travma yardımında dengeli reanimasyon ve hasar kontrol cerrahisine (HKC) bağlılık da dahil olmak üzere mortaliteyi öngören faktörleri ve bunların sonuçlara yansımalarını tartışmayı ve kurumumuzun sonuçlarını literatürle karşılaştırmayı amaçlamaktadır.

**Gereç ve Yöntem:** İnför vena kava yaralanması olan hastaları araştırmak için Campinas Üniversitesi (UNICAMP) Klinik Hastanesi'ndeki travma hastalarının veri tabanı kayıtları üzerinden retrospektif bir tasarım analizi yapılmış ve mortaliteyi öngören faktörlere vurgu yapılmıştır.

**Bulgular:** Ocak 1990'dan Ağustos 2017'ye kadar 74 hastada İVK yaralanması tespit edilmiştir. Ağırıklı neden %87,8 ile penetran yaralanmaydı (%76,3 ateşli silah). Hastaneye varışta, tüm hastaların %37,8'i hipotansifti ve ISS ortancası 24,5 idi. İnför vena kavanın yeri açısından, %68,5'i infrarenal, %12,2'si suprarenal, %18,9'u retrohepatik idi. Hastaların %60,8'inde basit onarım yapıldı. Yüzde 27'sine ligasyon ve %4,1'ine atriyo-kaval şant uygulandı. Hastaların %8,1'inde spesifik ameliyat için yeterli zaman yoktu. Hastaların %97,3'ünde eşlik eden intra-abdominal yaralanma mevcuttu ve transfüzyon gereksinimi ortalama  $9,1 \pm 6,9$  paketlenmiş kırmızı kan hücresi idi. Genel mortalite oranı %52,7 olup, infrarenal yaralanmalar için mortalite oranı %39,2'ydı. Hasar kontrol cerrahisi %68 mortalite ile %33,8'inde uygulanmıştır.

**Sonuç:** Şok reanimasyonuna ilişkin sağlam bir anlayış giderek yaygınlaşmaktadır ancak travma bakım uzmanları, bunların dengeli bir reanimasyon ve HKC ile uygulandığından emin olmalıdır.

**Anahtar Kelimeler:** Abdominal vasküler yaralanma, hasar kontrol, inferior vena kava, ligasyon, mortalite, hipovolemik şok

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