

Measurement of Central Venous Pressure via the Femoral Route in Abdominal Compartment Syndrome

Gavin M. Joynt, Charles D. Gomersall, Gordon Choi, Po T. Chui

Abstract

Introduction: Femoral vein catheterization provides an alternative route of access to central veins, is technically easy and relatively safe. There is good evidence of a general agreement between intrathoracic central venous pressure (CVP) and CVP measured in the iliofemoral veins or inferior vena cava in critically ill patients. This agreement is not well documented when intra-abdominal pressure is raised.

Methods: Intra-abdominal and intrathoracic venous pressures were measured in two cases of abdominal compartment syndrome (ACS), who both had intrathoracic and femoral central venous catheters in place for clinical management. A PUBMED search was conducted to identify relevant studies or reports documenting the relationship between intrathoracic and intra-abdominal CVP, with special reference to conditions of raised intra-abdominal pressure or ACS.

Results: There are several sources of data confirming that under conditions of normal to moderately raised intra-abdominal pressure there is a close relationship between intrathoracic CVP and intra-abdominal CVP in critically ill patients, even during mechanical ventilation. There is little data documenting the relationship under conditions of raised intra-abdominal pressure, and no data under conditions of ACS. The two cases reported suggest that the normal close relationship is completely lost under conditions of ACS.

Conclusions: Vascular catheters inserted via the femoral route can be routinely used to measure CVP in most critically ill patients with normal or moderately raised intra-abdominal pressure (<15-20 mmHg), but should not be used to measure CVP in patients with abdominal compartment syndrome.

Key words: Central venous pressure, abdominal compartment syndrome, femoral vein catheterization.

From Chinese University of Hong Kong, Prince of Wales Hospital, Shatin, Hong Kong (Drs. Gavin M. Joynt, Charles D. Gomersall, Gordon Choi, and Po T Chui)

Address for correspondence:

Gavin M. Joynt MBBCh, FHKCA(IC), FJFICM
Department of Anaesthesia and Intensive Care
Chinese University of Hong Kong
Prince of Wales Hospital
Shatin
Hong Kong
Phone: (852) 2632 2735
Fax: (852) 2637 2422
Email: gavinmjoynt@cuhk.edu.hk

Introduction

There are many indications for central venous catheter insertion, such as acting as a conduit for the infusion of vasoactive drugs, hyperosmolar solutions and agents toxic to vascular endothelium, as well as an alternative cannulation route under conditions of difficult peripheral vascular access. In critically ill patients, central venous pressure (CVP) is commonly used as a reflection of the preload of the heart. Catheter insertion via the internal jugular and subclavian vein may result in complications such as carotid artery puncture,

hemorrhage, pneumothorax, air embolism and damage to adjacent nerves [1]. Femoral vein catheterization provides an alternative route of access to central veins and is technically easier because of its superficial and consistent position in relation to the femoral artery [2]. Although there are attributable complications of femoral vein catheterization such as an increased risk of lower limb deep venous thrombosis [3], and a small increase in infectious complications [4,5], the route is a useful under many circumstances. Femoral venous cannulation is frequently used in patients with limited venous access, such as burns or long stay patients, patients with severe coagulopathy, severe respiratory distress, or difficult head and neck anatomy. Studies have reported good clinical agreement between CVP measured in the superior vena cava (SVC), and the inferior vena cava (IVC) or common iliac veins in mechanically ventilated critically ill patients [6,7]. We report two cases of abdominal compartment syndrome (ACS) in patients who both had intrathoracic and femoral central venous catheters in place, allowing simultaneous measurement of intrathoracic and intra-abdominal central venous pressures. The relevant literature relating to CVP measurement via the femoral route and the influence of intra-abdominal hypertension on its relationship to intrathoracic CVP is reviewed.

Case reports

Case 1

A 52-year-old male patient with rapidly deteriorating severe hemorrhagic pancreatitis was admitted to the intensive care unit for physiological monitoring, ventilation and cardiovascular support with intravenous fluid resuscitation and inotropic infusion. Because the patient was severely coagulopathic, central venous access was obtained via the femoral route. The catheter tip was placed in the IVC at a skin depth of 39 cm to allow measurement of central venous pressure close to the right atrium (CVP) as previously described and validated [3]. On day 6 the patient demonstrated acute clinical deterioration requiring increase in fluid resuscitation. At this time mild abdominal distention was noticed and intra-abdominal pressure was

measured via a urinary catheter using a previously described technique [8]. Fluid resuscitation consisted of three liters of crystalloid and colloid solution over 4-5 hours. Persistent hypotension resulted in the need for inotropic support with dobutamine at 4 $\mu\text{g}/\text{kg}/\text{minute}$ and noradrenaline 0.14 $\mu\text{g}/\text{kg}/\text{minute}$. This resuscitation was followed by a sudden and marked increase in abdominal distention, oliguria and worsened pulmonary compliance and the CVP abruptly increased from 13 to 25 mmHg (hourly CVP readings over the preceding 8 hours had ranged from 8 to 16 mmHg) (**Figure 1**). The patient became hypotensive and to facilitate further resuscitation, additional intravascular access was required. After appropriate correction of the coagulopathy, a size of 7F right internal jugular venous catheter was inserted. The tip was confirmed to be in the SVC, approximately 5 cm to the right atrium on chest radiograph. The CVP measured from this catheter was found to be 17 mmHg. CVP measurement from the inferior vena cava that was repeated at the same time was 35 mmHg, well above CVP measured from the superior vena cava and similar to the intra-abdominal pressure (36 mmHg) (**Figure 1**). A CT scan performed to delineate intra-abdominal pathology showed incidentally that the IVC was collapsed (**Figure 2**). Despite continued organ support, the patient's condition continued to deteriorate and he died from multiple organ failure 7 days after ICU admission.

Case 2

A 20-year-old female patient fell from a height of more than 10 m and suffered injuries that included fractures of the maxilla, mandible, bilateral ribs, right femur, and multiple fractures of the pelvic ring. She also suffered a traumatic subarachnoid haemorrhage and bilateral pulmonary contusions. She was admitted to the intensive care unit after laparotomy and external fixation of the pelvis. A large retroperitoneal haemorrhage had been identified intraoperatively, requiring crystalloid fluid replacement and 17 units of packed red blood cells, 16 units of fresh frozen plasma, 12 units of cryoprecipitate and 12 units of platelet concentrate. On arrival in the ICU she was haemodynamically unstable, requiring ongoing fluid

resuscitation with crystalloid and colloid solutions and a further four units of packed red blood cells, 4 units of fresh frozen plasma and 10 units of platelets. A 20 cm femoral venous catheter was in situ and central venous pressure was measured hourly (**Figure 3**). An increasingly tense, distended abdomen was observed and intra-abdominal pressure measured six hours after admission to the ICU and then approximately every 2nd hour (**Figure 3**). The increased intra-abdominal pressure was associated with increased airway pressure, gradually reducing urine output and worsening hepatic function. Despite resuscitation, the patient required vasopressor support (epinephrine 0.06 µg/kg/minute to maintain a mean arterial pressure of 70 mmHg); and to improve vascular access, a left subclavian central venous catheter was placed. The tip was confirmed on radiograph to be in the superior vena cava. The initial and subsequent CVP measurements from the subclavian catheter were found to be substantially lower than that measured from the femoral catheter (**Figure 3**). By 12h post-operative bleeding had stabilized and by 36h intra-abdominal pressure had returned to 16 mmHg, and the femoral catheter was removed. The CVP measured simultaneously via the femoral catheter and subclavian catheter at the time of removal (36h post operatively) was 21 mmHg and 19 mmHg respectively. The patient's condition continued to improve and she was discharged to the general ward on day 14.

Discussion and review

The two cases presented both meet the criteria for ACS - a sustained IAP of greater than 20 mmHg that is associated with new organ dysfunction or failure [9]. It is clear from the simultaneous recordings of central venous pressure via the femoral and thoracic routes that the intra-abdominal and intrathoracic CVP were markedly different in the presence of ACS. The intra-abdominal venous pressures appear to reflect the high intra-abdominal pressure, and not measured intrathoracic CVP.

The likely pathophysiological explanation for this difference is as follows. The normally close agreement

between intrathoracic and intra-abdominal venous pressure relies on four main factors – the absence of any anatomical valves in the veins under consideration, the maintenance of a continuous fluid column from the right atrium to the relevant catheter tips, the relatively slow venous flow and relatively large diameter of both the inferior and superior vena cava. Therefore, resistive pressure differences between the catheter tips, or the right atrium, are minimal and it is reasonable to assume that venous pressure at these points will be similar. Studies have confirmed this relationship in humans [6,7]. However, in the presence of excessively high intra-abdominal pressure (manifested by ACS), external pressure causes the vena cava to narrow and even intermittently collapse as shown in **Figure 2**. This results in much higher resistance to flow and it is even possible that the connecting fluid column becomes intermittently obliterated. The former condition would lead to a substantial pressure difference being required to overcome the resistance between the intra-abdominal venous system and the right atrium to maintain venous return flow, while in the latter condition it is likely that an intermittent “waterfall” effect could occur, both leading to a large pressure difference between intra-abdominal and intrathoracic venous pressure.

It is likely that under conditions of ACS, with increasing narrowing of the inferior vena cava, the pressure measured by a catheter placed in the intra-abdominal vessels will increase and approach the value of the external pressure that has caused the vessel to collapse - in this case the value of pathologically raised intra-abdominal pressure.

It might be expected that the positioning the tip of the catheter close to the diaphragm and right atrium would attenuate the effect of high intra-abdominal pressure. While in case 2 the catheter tip was in the iliofemoral vessels, the catheter tip in case 1 was placed in the inferior vena cava, close to the right atrium as seen on CT scan, however the effect of the ACS on femoral catheter tip pressure does not appear to have been reduced.

Lastly the effect of venous pressure within the inferior vena cava needs to be considered. To cause narrowing

or collapse of the inferior vena cava, external pressure must exceed internal pressure, therefore, it seems likely that when intravascular volume and pressure is lower, the intra-abdominal pressure required to cause narrowing will be less [10,11]. Some suggestive evidence to this effect has been documented in a study comparing superior vena cava pressure, inferior vena cava pressure and intra-abdominal pressure [12]. Although the absolute changes were not large and intra-abdominal pressure only moderately high, the study found that under conditions of moderately raised intra-abdominal pressure, when intra-abdominal pressure exceeded superior vena cava pressure, the relationship between inferior vena cava pressure and intra-abdominal pressure was slightly stronger than that between inferior vena cava pressure and superior vena cava pressure. When superior vena cava pressure exceeded intra-abdominal pressure, the inferior vena cava pressure and superior vena cava pressure remained highly correlated [12].

A PUBMED search was conducted to identify articles that compared the measurement of intra-abdominal venous pressure (from common femoral vein to inferior vena cava) with superior vena cava or right atrial pressure in critically ill patients. In addition, studies that also reported intra-abdominal pressure were identified. The following key words were used: femoral venous catheter AND venous pressure AND abdominal pressure; inferior vena cava pressure OR femoral venous pressure AND measurement; abdominal compartment syndrome AND venous pressure. The search was limited to adult and human reports and only articles reporting data in critically ill patients were retrieved and reviewed for relevance. Other relevant articles were obtained from reference lists.

Six studies were identified [6,7,12-15], of which three [6,7,12] reported simultaneously measured intra-abdominal pressure. Studied groups included general ICU patients [6,7,12,14], burns patients [13], and those receiving inverse ratio mechanical ventilation [15]. All studies reported a generally close agreement between intrathoracic and intra-abdominal venous pressures.

Although all studies reported a close correlation only four studies reported mean differences and limits of agreement. Reported mean differences (intrathoracic - intra-abdominal venous pressures) ranged from 0.1 to 0.93 mmHg, with 95% limits of agreement ranging from -2.04 to 2.23 mmHg in these four studies [6,7,14,15].

Two studies showed consistently close agreement between intrathoracic and intra-abdominal venous pressures in patients with normal to moderate increases of intra-abdominal pressure (up to 22 cmH₂O) [6,7], however, one study demonstrated a moderate decline in agreement when intra-abdominal pressure was both raised (>15 mmHg) and exceeded superior vena cava pressure [12]. Specifically, when intra-abdominal pressure exceeded superior vena cava pressure, femoral venous catheter tip pressure more closely correlated with intra-abdominal pressure than intrathoracic CVP [12].

Therefore, the majority of data support the conclusion that the central venous pressure reading is equally reliable if the central line is inserted via the femoral vein [16]. Studies that have measured intra-abdominal pressure confirm that this relationship is valid under conditions of moderately raised intra-abdominal pressure. However, when intra-abdominal pressure is more than moderately raised, there is little data confirming this relationship.

Conclusion

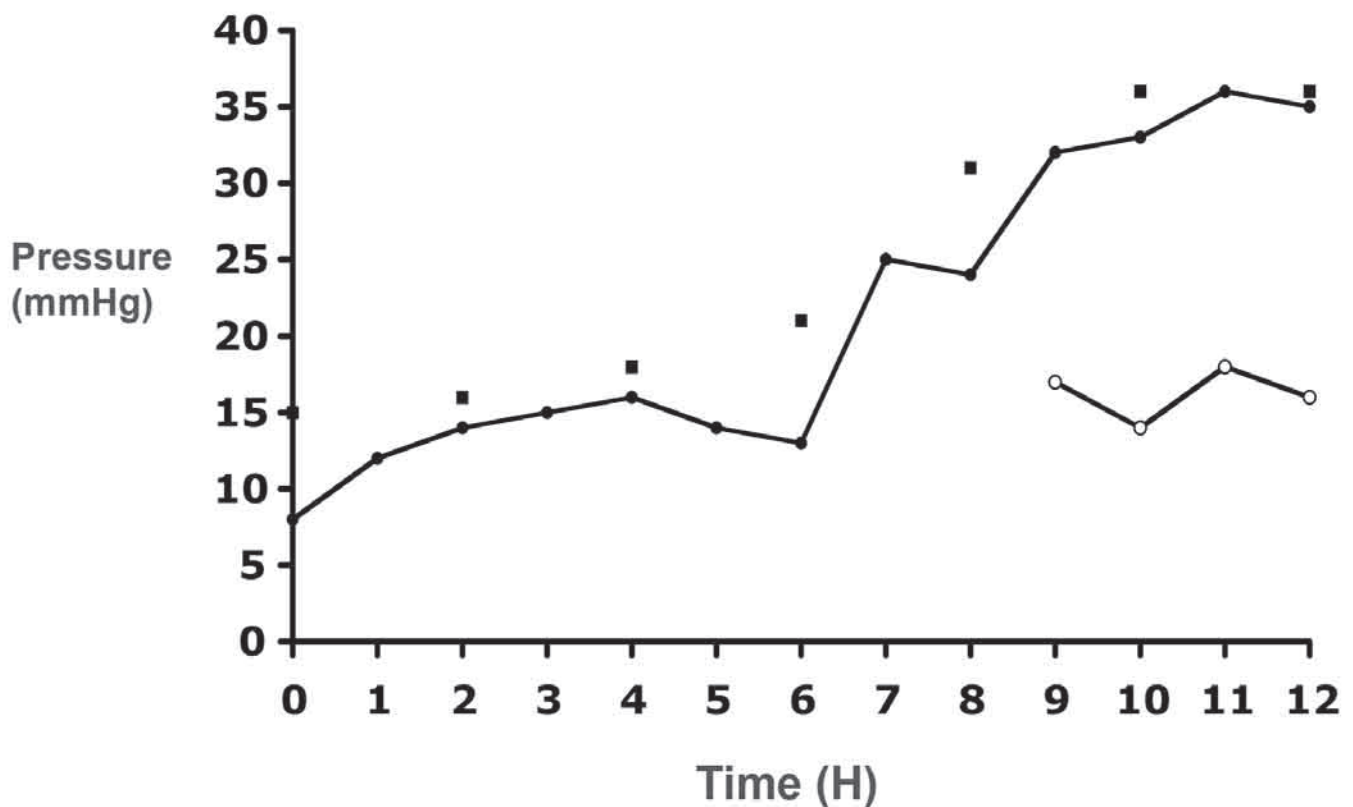
There is substantial evidence that the agreement of intrathoracic venous pressure (CVP) and intra-abdominal venous pressure in the majority critically ill patients is good. However, the cases presented suggest that this agreement will be lost in the presence of severe intra-abdominal hypertension (>15-20 mmHg), or abdominal compartment syndrome. Abdominal compartment syndrome is not uncommon with an incidence of approximately 3-10% in critically ill patients in intensive care, depending on case-mix.

Therefore, while vascular catheters inserted via the femoral route can be routinely used to measure CVP in most critically ill patients, they should not be used to measure CVP in patients with severe intra-abdominal hypertension or abdominal compartment syndrome. In addition, if CVP is being measured using the IVC, any sudden increase in IVC pressure to unexpectedly high levels may serve as a warning of possible abdominal compartment syndrome.

Acknowledgements

The authors would like to thank Dr. R. Calcroft who assisted in the management of one of the clinical cases and in the collection of clinical data.

Figure 1. PRESSURE TIME RELATIONSHIP (CASE 1)



Legend: intra-abdominal pressure (squares), CVP measured in the inferior vena cava from the long femoral line (closed circles), and intrathoracic CVP (open circles).

Time 0h is when the intra-abdominal pressure was first measured following the onset of abdominal distention on day 6. The internal jugular central venous catheter was placed 9 hours later.

Figure 2. CONTRAST ABDOMINAL CT SCAN

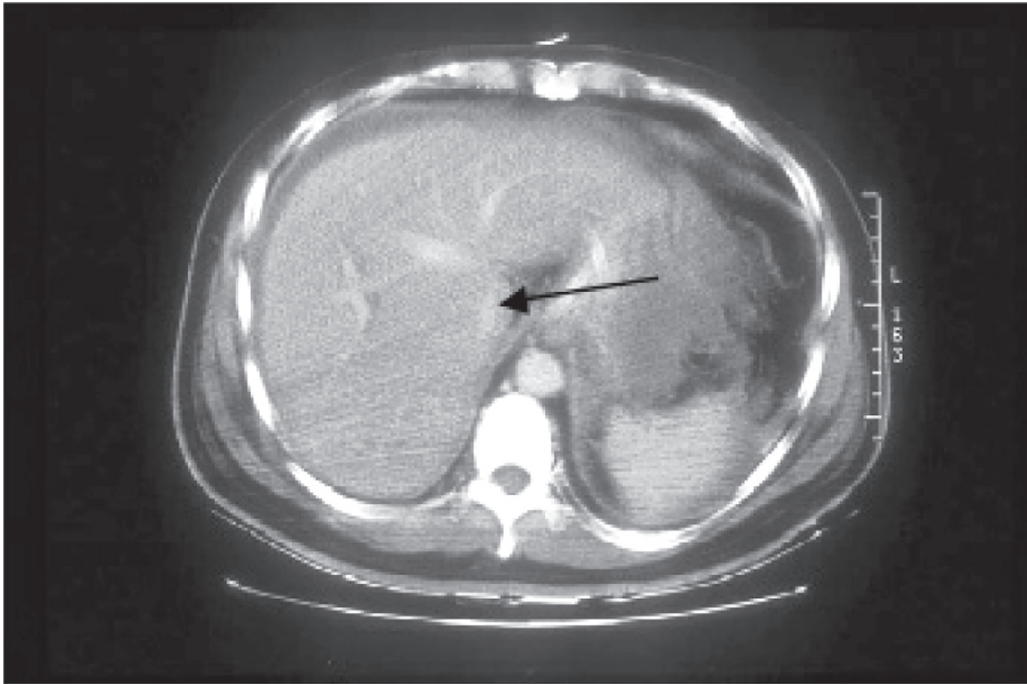


Figure 2a

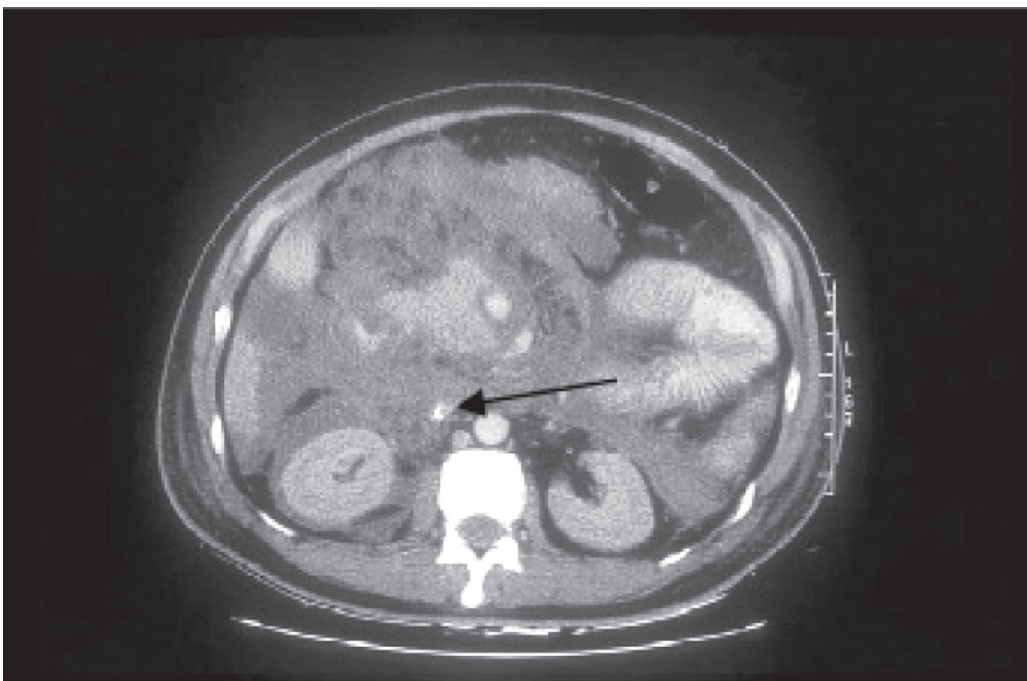
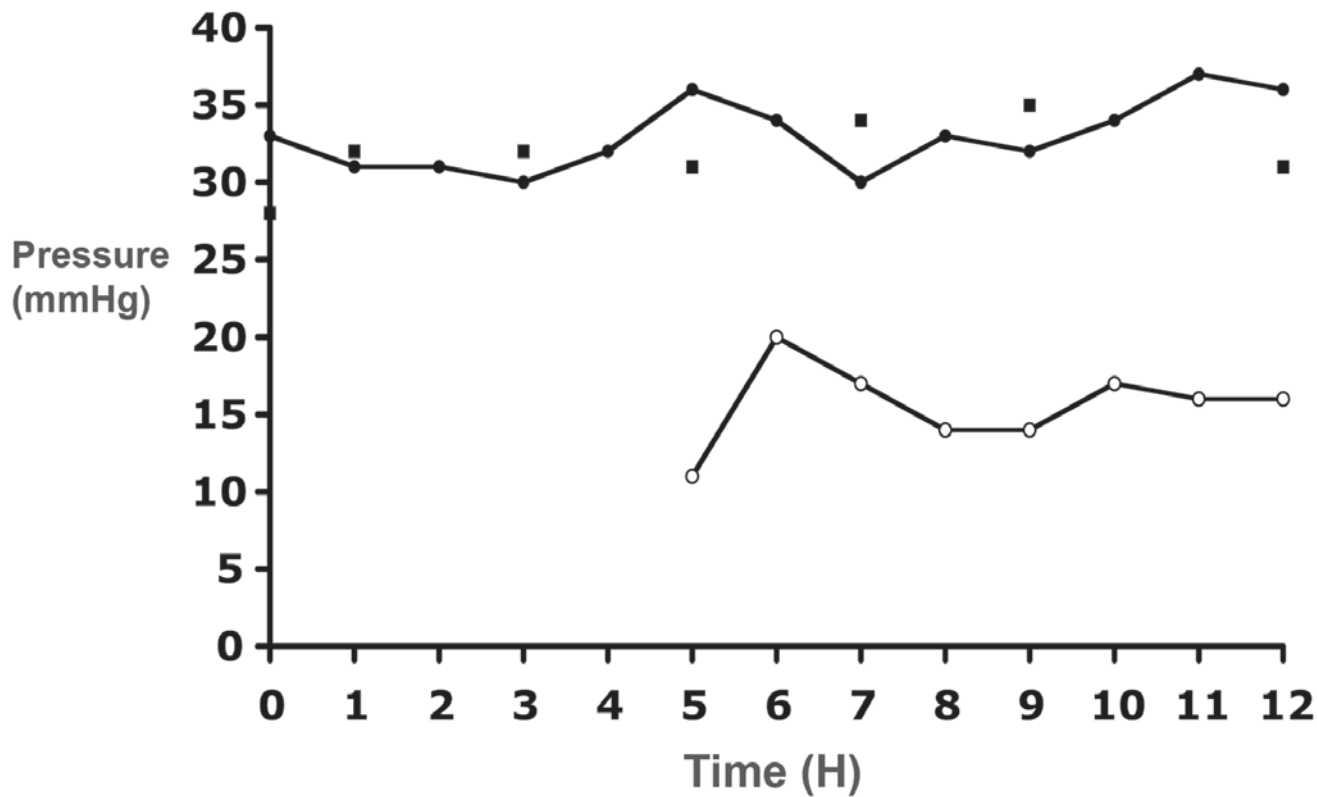


Figure 2b

Legend: acute inflammatory changes of pancreatitis and collapse of the inferior vena cava (arrows). Sections cut at 3cm (a) and 15cm (b) below the diaphragm. In (b) femoral central line is visible within the collapsed inferior vena cava.

Figure 3. PRESSURE TIME RELATIONSHIP (CASE 2)



Legend: intra-abdominal pressure (squares), CVP measured in the inferior vena cava from the femoral line (closed circles), and intrathoracic CVP (open circles).

Time 0h is when the intra-abdominal pressure was first measured six hours after admission to ICU. The subclavian central venous catheter was placed 5 hours later.

References

1. Agee KR, Balk RA (1992) Central venous catheterization in the critically ill patient. *Crit Care Clin* 8:677-686
2. Williams JF, Seneff MG, Friedman BC, McGrath BJ, Gregg R, Sunner J, Zimmerman JE (1991) Use of femoral venous catheters in critically ill adults: prospective study. *Crit Care Med* 19:550-553
3. Joynt GM, Kew J, Gomersall CD, Leung VY, Liu EK (2000) Deep venous thrombosis caused by femoral venous catheters in critically ill adult patients. *Chest* 117:178-183
4. Merrer J, De Jonghe B, Golliot F, Lefrant JY, Raffy B, Barre E, Rigaud JP, Casciani D, Misset B, Bosquet C, Outin H, Brun-Buisson C, Nitenberg G; French Catheter Study Group in Intensive Care (2001) Complications of femoral and subclavian venous catheterization in critically ill patients: a randomized controlled trial. *JAMA* 286:700-707
5. Lorente L, Henry C, Martín MM, Jiménez A, Mora ML (2005) Central venous catheter-related infection in a prospective and observational study of 2,595 catheters. *Crit Care* 9:R631-635
6. Joynt GM, Gomersall CD, Buckley TA, Oh TE, Young RJ, Freebairn RC (1996) Comparison of intrathoracic and intra-abdominal measurements of central venous pressure. *Lancet* 347:1155-1157
7. Ho KM, Joynt GM, Tan P (1998) A comparison of central venous pressure and common iliac venous pressure in critically ill mechanically ventilated patients. *Crit Care Med* 26:461-464
8. Iberti TJ, Lieber CE, Benjamin E (1989) Determination of intra-abdominal pressure using a transurethral bladder catheter: clinical validation of the technique. *Anesthesiology* 70:47-50
9. Malbrain ML, Cheatham ML, Kirkpatrick A, Sugrue M, Parr M, De Waele J, Balogh Z, Leppäniemi A, Olvera C, Ivatury R, D'Amours S, Wendon J, Hillman K, Johansson K, Kolkman K, Wilmer A (2006) Results from the International Conference of Experts on Intra-abdominal Hypertension and Abdominal Compartment Syndrome. I. Definitions. *Intensive Care Med* 32:1722-1732
10. Vieillard-Baron A, Chergui K, Rabiller A, Peyrouset O, Page B, Beauchet A, Jardin F (2004) Superior vena caval collapsibility as a gauge of volume status in ventilated septic patients. *Intensive Care Med* 30:1734-1739
11. Barbier C, Loubières Y, Schmit C, Hayon J, Ricôme JL, Jardin F, Vieillard-Baron A (2004) Respiratory changes in inferior vena cava diameter are helpful in predicting fluid responsiveness in ventilated septic patients. *Intensive Care Med* 30:1740-1746
12. Markou N, Grigorakos L, Myrianthefs P, Boutzouka E, Rizos M, Evagelopoulou P, Apostolakis H, Baltopoulos G (2004) Venous pressure measurements in the superior and inferior vena cava: the influence of intra-abdominal pressure. *Hepatogastroenterology* 51:51-55
13. Sheridan R, Nackel A, Lydon M, Petras L, Basha G (1999) Infradiaphragmatic central venous pressures reflect supradiaphragmatic pressures in stable burn patients. *J Trauma* 47:300-302
14. Alzeer A, Arora S, Ansari Z, Fayed DF, Naguib M (1998) Central venous pressure from common iliac vein reflects right atrial pressure. *Can J Anaesth* 45:798-801
15. Dillon PJ, Columb MO, Hume DD (2001) Comparison of superior vena caval and femoroiliac venous pressure measurements during normal and inverse ratio ventilation. *Crit Care Med* 29:37-39
16. Desmond J, Megahed M (2003) Is the central venous pressure reading equally reliable if the central line is inserted via the femoral vein. *Emerg Med J* 20:467-469
17. Malbrain ML, Chiumello D, Pelosi P, Bihari D, Innes R, Ranieri VM, Del Turco M, Wilmer A, Brienza N, Malcangi V, Cohen J, Japiassu A, De Keulenaer BL, Daelemans R, Jacquet L, Laterre PF, Frank G, de Souza P, Cesana B, Gattinoni L (2005) Incidence and prognosis of intraabdominal hypertension in a mixed population of critically ill patients: a multiple-center epidemiological study. *Crit Care Med* 33:315-322