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ORIGINAL ARTICLE

Comparison of Intra Abdominal Pressure Monitoring Techniques and the Effects of the Abdominal Compartment Syndrome on Renal Blood Flow in an Anesthetized Pig Model

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ABSTRACT

Background: Abdominal compartment syndrome (ACS) is a life-threatening condition that develops in the setting of increasing and uncontrolled intra-abdominal hypertension (IAH), leading to cardiovascular, respiratory, neurologic and/or renal dysfunction.
Aims: To establish a porcine model for the evaluation of the effects of IAH on renal blood flow (RBF) and to determine if IVC pressure and/or Camino fiberoptic direct intraabdominal pressure measurements can accurately predict IAPs that have been derived using bladder pressure measurements.
Methods: Abdominal laparotomy, placement of IAP and RBF measuring devices, and fascial closure were performed on six adult feeder pigs with a mean body weight of 25 +/- 5 kg. A Transonic Doppler flow probe, a suprapubic bladder catheter, a Camino fiberoptic probe, and a triple lumen central venous catheter were placed and then baseline measurements were taken of renal blood flow, bladder pressure, direct intra-peritoneal Camino pressure and IVC pressure, respectively. Normal saline was then infused into the abdomen to simulate increasing IAP. Following a 5–10-minute stabilization period, all measurements were again taken.
Results: The correlation between IVC pressure and bladder pressure was 0.98, with a mean bias of -0.5 (SD 2.0; 95% CI: -0.9, -0.2). The correlation between direct IAP readings by Camino probe and bladder pressure was 0.91, with a mean bias of -3.9 (SD 4.3; 95% CI: -4.6, -3.2). There was a strong negative correlation (-0.95) between RBF and bladder pressure. At an IAP of 20 mmHg, RBF reduced by an average of 45.4% (95% CI: 40%, 50.8%). Upon abdominal decompression, RBF returned to 66.6% (95% CI: 54.3%, 78.9%) of its baseline value.
Conclusions: A porcine model is effective in accurately measuring changes in real time RBF. RBF progressively declines as IAP increases, however upon decompression, it fails to achieve complete recovery. IVC pressure measurements correlate well with, and therefore may substitute, the gold standard bladder pressure measurements as representatives of IAP.
Keywords: Abdominal Compartment syndrome, renal blood flow, intrabdominal hypertension, bladder pressure.

INTRODUCTION

Goals: The goals of this study were to establish a porcine model (1)(2) for the evaluation of the effects of intra abdominal hypertension on renal blood flow (RBF) as measured by a Transonic Doppler flow probe. These experiments were also designed to study and compare the correlation between three different intra abdominal pressure monitoring techniques; urinary bladder pressure, intra abdominal Fiber optic Camino probe pressures and IVC pressure measurements.
Hypothesis: The effects of intra abdominal hypertension and the abdominal compartment syndrome on various organ systems have been well documented (3). Renal blood flow is significantly compromised by raised intra abdominal pressure. Urinary bladder pressure monitoring is the technique that is principally used to monitor the intra-abdominal pressure (IAP). We postulated that the inferior vena cava (IVC) and direct intraabdominal cavity pressure measured via a fiberoptic camino probe could substitute for the standard urinary bladder pressure measurement of intra abdominal pressure.

We also hypothesized that renal blood flow may show either continuous gradual decline with increasing IAP or have an IAP threshold after which there is a rapid decline in renal blood flow. Renal blood flow should also show a return to normal with release of intra abdominal hypertension secondary to the development of an intra-abdominal compartment syndrome.

METHODS & MATERIAL

After obtaining institutional review board approval (IRB) the study was conducted using six adult swine (feeder pigs) as test subjects (TS). The animals were between 20-30 kg. Equipment included transonic renal blood flow measuring probes (Fig 1, 2), fiberoptic ICP measuring camino probe and monitoring and infusion lines.

The TS were positioned in a supine position and pre-anesthetized with ketamine and xylazine. Anesthesia was maintained by Isoflurane, and they were ventilated via an endotracheal tube at a set rate and with tidal volume of 15ml/kg. A triple lumen central venous catheter placed in IVC by means of femoral cut down. Bladder pressure was measured by Ilberti (suprapubic) technique. A laparotomy was performed, and transonic Doppler flow probe was positioned around the right renal artery (Fig 3). A camino fiberoptic ICP probe was zeroed and positioned in peritoneal cavity (Fig 4). Infusion catheters were placed in the abdomen and the abdominal fascia was then closed (Fig 5).

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Baseline measurements of bladder pressure, renal blood flow, camino pressure and IVC pressure were taken. Arterial blood pressure, heart rate and continuous SpO2 were monitored throughout the experiment.

Saline was infused into the abdomen to raise the intra-abdominal pressure. Bladder pressure, renal blood flow, camino pressure and IVC pressure measurements were taken after a 5–10-minute stabilization period. Readings were taken from rest to a maximum pressure of 40mmHg, with increments of 5 mmHg, using bladder pressure measurement as the control value.

Abdominal decompression was then performed, and readings were taken as the pressure was decreased. Hemodynamic were kept constant and normotension was maintained during the experiment with IV fluid administration. The swine were euthanized at the end of the experiment

Statistical analysis: Agreement of the IVC pressure and the Camino probe pressure measurements with the bladder pressure readings were assessed by determining the correlation and by estimating the bias (difference) between each method with the bladder pressure. Random coefficients linear regression model was used to estimate the percent decrease in RBF as a function of increasing abdominal pressure.

RESULTS

The correlation of IVC pressure with bladder pressure was 0.98 with a mean bias of -0.5 (SD 2.0; 95% CI: -0.9, -0.2) (Fig 6). Bladder pressure was compared with the camino probe. The Camino probe had a correlation of 0.91 with bladder pressure with a mean bias -3.9 (SD 4.3; 95% CI: -4.6, -3.2) (Fig 7).

Effects of progressively rising intra-abdominal pressure resulted in a lowered renal blood flow (Fig 8). All pigs showed an immediate return to a lower than baseline RBF rates on abdominal decompression (Fig 9). The inverse relationship of increasing IAP to RBF was preserved when measured by different techniques. There was a strong correlation (-0.95) between RBF and bladder pressure. At an abdominal pressure of 20 mmHg, RBF had been reduced by an average of 45.4% (95% CI: 40.0%, 50.8%). When the abdomen was decompressed, RBF returned to only 66.6% (95% CI: 54.3%, 78.9%) of its original value.

Fig 1: Transonic Flow probe

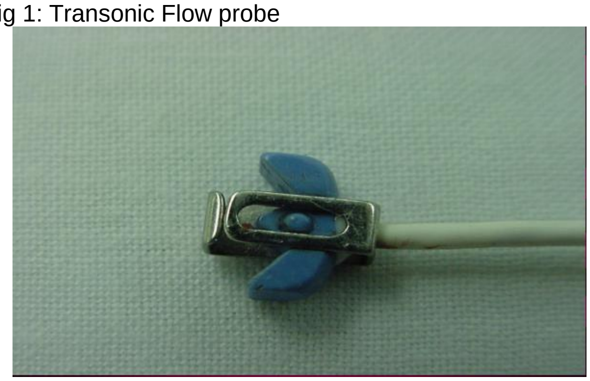


Fig 2: Flow measuring unit

Fig 3: Flow probe on renal artery

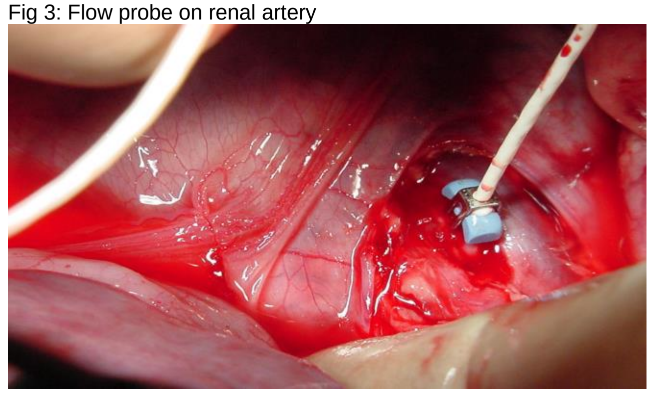


Fig 4: Camino probe in peritoneum

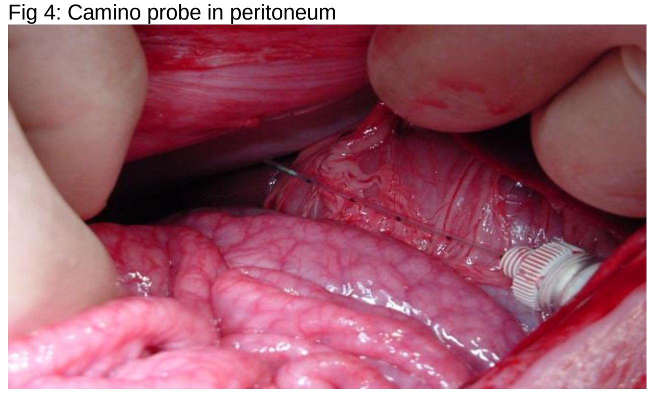


Fig 5: Final set up with monitoring lines, infusion and cutdown catheters in place.

Fig 6: IVC vs. Bladder Pressure

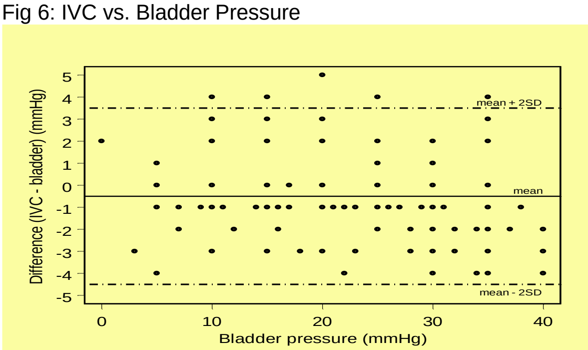


Fig 7: Camino vs. Bladder Pressure

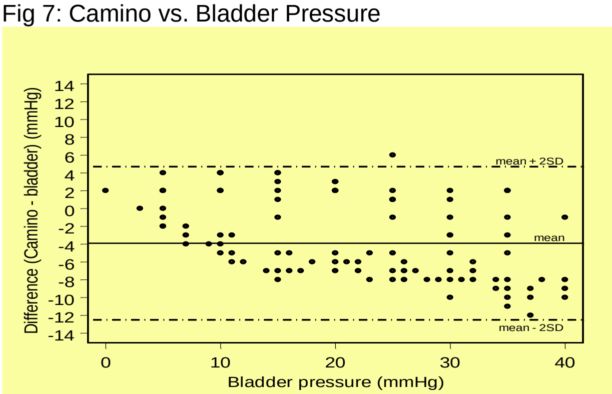


Fig 8: Increasing Bladder Pressure vs. RBF

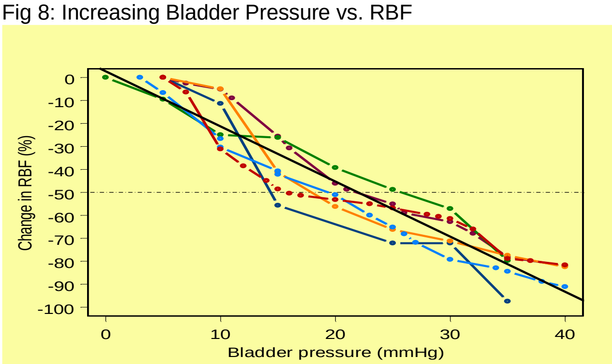
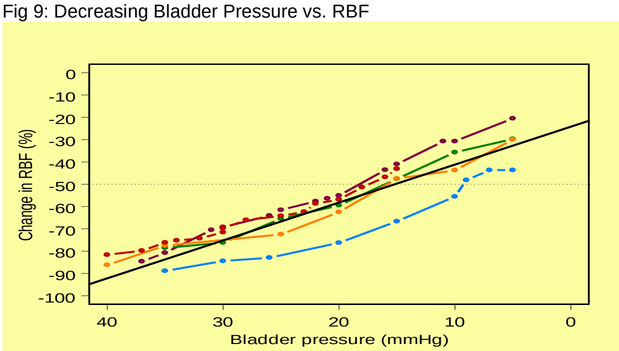


Fig 9: Decreasing Bladder Pressure vs. RBF



DISCUSSION

Abdominal compartment syndrome (ACS) or intra-abdominal hypertension (IAH) can occur as a complication in many clinical scenarios such as in patient with visceral edema, shock and reperfusion, hemoperitoneum, retroperitoneal edema, acute pancreatitis, paralytic ileus, small bowel obstruction etc. and is a dangerous feature in these critically ill patients, leading to increased mortality and poorer outcomes[4].IAH has profound effects on multiple organ system functions[5,6]. The cardiovascular effects of IAH include a decreased venous return, increased systemic vascular resistance, increased intrathoracic pressure, decreased cardiac output, and inferior vena cava compression. The IAH leads to an elevated diaphragm, decreased compliance, altered ventilation perfusion ratio/ increased shunting, increased peak airway and plateau pressures and worsening gas exchange and hypoxia[7]. The renal effects of IAH are profound. Approximately Twenty five percent of Cardiac output goes to the kidney. IAH causes oliguria and increased cardiac output does not restore renal flow. There is also a corticomedullary shift of RBF associated with IAH. These effects are seen in adults and pediatric patients[5].

The diagnosis is made in the appropriate clinical setting where the patient develops a tense/distended abdomen with increased peak airway pressures, oliguria and decreased cardiac output associated with an elevated measured intra-abdominal pressure. Pressure levels at which ACS occurs are not conclusively defined 25 mm Hg considered physiologically significant and 25-30mmHg generally warrants surgical intervention[8]. IAH has been graded as Grade I (12mm-15mmHg), Grade II (16-20mmHg), Grade III (20-25mmHg) and Grade IV (>25mmHg)[9].

There are different techniques that can be used to measure IAH. Currently bladder pressure is the “gold standard”[10] and most commonly used clinically to measure intra- abdominal pressure[11]. Once ACS develops an early intervention with a decompressive laparotomy (DL) is usually necessary to prevent an adverse outcome[12,13]. A limitation to fluid resuscitation has been reported to have contributed to an apparent decrease in ACS among critically ill patients[13]. In our experiment IVC pressure correlated well against bladder pressure but direct intra peritoneal pressure measurement proved inaccurate and unreliable. Other studies have also raised questions regarding the accuracy of different techniques[14]. World Society of the Abdominal Compartment Syndrome (WSACS) has defined the requirements for good agreement between different techniques[15].

Renal blood flow has been known to be compromised rapidly in patients with ACS. Our study confirmed these findings and showed that there was a significantly rapid and profound decrease in RBF in the setting of IAH.

CONCLUSIONS

Porcine model has proved effective in accurately measuring changes in real time renal blood flow. The RBF shows a progressive decline as intra-abdominal pressure increases, and an incomplete recovery on decompression. IVC pressure measurement correlates well with the gold standard bladder pressure measurements and can be used as a substitute technique. Direct IAP readings with a Camino probe are not sensitive nor accurate enough to have clinical applications

Conflict of interest: Nil

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