JOURNAL OF SURGICAL RESEARCH • OCTOBER 2022 (278) 100–110

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Intra-abdominal Pressure Monitoring During Negative Pressure Wound Therapy in the Open Abdomen

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ARTICLE INFO

Article history:
Received 10 December 2021
Received in revised form
11 March 2022
Accepted 8 April 2022
Available online 18 May 2022

Keywords:
Damage control laparotomy
Delayed abdominal closure
Negative pressure wound therapy
Open abdomen

ABSTRACT

Introduction: Negative pressure wound therapy (NPWT) is commonly used in open abdomen management, where there may be a simultaneous need for prevention of abdominal hypertension, tamponade of hemorrhage, and continuous fascial tension. The regional pressure dynamics of vacuum dressings are poorly understood.

Methods: Three duroc swine underwent mid-line laparotomy and application of vacuum open abdomen dressing, with and without sponge packing. Twenty-five catheters were placed throughout the abdomen to capture and record pressures in each quadrant as the vacuum system was ranged between (−75 mmHg to −200 mmHg pressure). Vital signs and ventilator pressures were measured and recorded concomitantly.

Results: No variations in ventilatory pressures or vital signs were observed with any setting. NPWT changed pressure in seven of seventy-five catheters (9%), five of which were related to abdominal packing. When data were grouped into abdominal wall, perihepatic, perisplenic, and deep abdominal regions, there was no significant change in abdominal pressure when packing was absent. With packing, only the abdominal wall region showed a pressure change, reaching a maximum of 20% of the set vacuum pressure.

Conclusions: NPWT does only little to change the intraabdominal pressure, except in superficial locations in packed abdomens and does not appear to cause hemodynamic changes in a porcine open abdomen model. While NPWT may play an important role in fluid scavenging and fascial tensioning, there are likely to be few benefits or drawbacks specifically related to negative abdominal pressure in the deep abdomen.

Introduction

Goals in open abdomen management include prevention or treatment of intraabdominal hypertension, drainage of abdominal fluids, continuous fascial tension, and ease of reentry into the abdomen.[1-3] Negative pressure wound therapy (NPWT) has become a frequent and favored choice by many for management of the open abdomen,[2-5] and use of

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https://doi.org/10.1016/j.jss.2022.04.019

the ABTHERA Open Abdomen Negative Pressure Therapy System (ABTHERA) (Kinetic Concepts, Inc, San Antonio, TX) has been employed for a variety of clinical scenarios, including traumatic injury, necrotizing pancreatitis, ruptured abdominal aortic aneurysm, bowel incarceration, and anastomotic leak.[6]

NPWT has become ubiquitous in the care of critically ill and injured patients requiring damage control approaches. NPWT has been associated with achievement of primary fascial closure,[7,8] one of the primary goals of successful open abdomen management. However, the seemingly simple goal of applying negative pressure to the open abdominal wound is in fact complicated by several competing concerns and imperatives. The vacuum dressing is expected to prevent abdominal hypertension, while simultaneously supporting local tamponade (elevated pressure), and providing fascial tension. The ability of NPWT to meet these varying pressure/vacuum needs are largely unproven.

Several specific concerns exist related to abdominal NPWT. A number of authors have raised suspicion that intra-abdominal negative pressures are translated to bowel wall with associated development of visceral malperfusion or enteric fistulae.[1,9-11] One group estimated a high incidence of fistulization at 20%,[12] while others report lower rates of 2%-6%.[13-16] The mean percentage of patients with fistula development associated with open abdominal NPWT in the literature appears to be 5%.[1] Cases of abdominal sepsis have been associated with these higher rates, though it is unclear if NPWT plays a causative role in these complications.[12] Some authors have suggested that ischemia may be demonstrated in the intestinal wall when positioned near NPWT dressing materials and that this ischemia is related to the level of negative pressure applied when using NPWT for management of open abdominal wounds.[17,18]

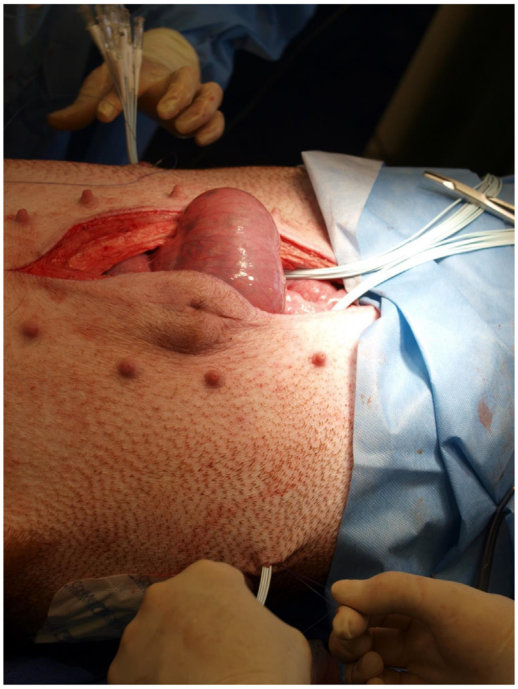

Fig. 1 – Catheters entered the abdomen through lateral abdominal wall incisions, then were placed in the locations diagrammed in Figure 2.

Another potential concern is Volume Reserve Capacity, or the ability of a temporary abdominal closure (TAC) to allow the intra-abdominal contents to expand and reduce intra-abdominal pressure.[19,20] Among various TAC devices, one study found that NPWT approaches were able to provide least this reserve capacity.[19] One theory to explain this phenomenon included less compression of the NPWT sponge at less intense negative pressure settings, leading to reduced available abdominal cavity volume.[20] This limitation to volume expansion presumably may contribute to abdominal hypertension, though this has not been shown in experimental studies.

Paradoxically, there is also a concern that application of NPWT may result in immediate increase in intra-abdominal pressure[15,19] and a higher rate of abdominal compartment syndrome than in patients treated with other TAC methods.[19,21] The pressure environment within the abdomen during treatment with NPWT is not well-documented in the literature. Bench top studies have been conducted to illustrate the negative pressure distribution through various materials used for this therapy,[22] but, *in vivo* pressure distribution has been mostly speculative. Occasional case reports have pointed out recurrent abdominal compartment syndrome after decompressive laparotomy and application of NPWT. One report in particular noted the association of higher intra-abdominal pressures with the administration of NPWT suction, and, conversely, improvement in intra-abdominal pressures when NPWT was discontinued.[23] There are some surgeons who advise against the immediate application of open abdomen NPWT secondary to these concerns, and instead recommend its application at the first dressing change. Others have evaluated their results after immediate application of NPWT and found it safe and effective.[11] One theory states that, as abdominal wall compliance decreases, as may be seen in intra-abdominal hypertension, the abdominal contour becomes less distensible, and intra-abdominal pressure becomes more evenly distributed throughout the abdomen, lessening the importance of the location of pressure determination.[24] In a multicenter trial comparing open abdomen NPWT with the traditional Barker's vacuum packing technique, intra-abdominal pressures measured during the study did not differ significantly (17 ± 6 *versus* 19 ± 7 mmHg), though these measurements were inconsistently taken.[25] The specialized ABTHERA Fenestrated Visceral Protective Layer dressing included with NPWT therapy packs is said to remove peritoneal fluid from deep within the abdomen.[25,26]

Despite the popularity of NPWT, concerns exist about the impact of these dressings on bowel integrity, hemodynamic parameters, and distribution of negative pressure throughout the abdomen. This pilot study uses the ABTHERA NPWT system and extensive array of intra-abdominal pressure microtransducers, with and without intra-abdominal packing, to thoroughly investigate the potential transfer of negative pressure to various intra-abdominal locations. We hypothesized that the ABTHERA NPWT system would not confer negative pressure to various spaces within the abdomen nor impact measured physiologic parameters.

Methods

Animal work

All animal work described was reviewed and approved by the MedStar Health Research Institute's Institutional Animal Care and Use Committee . Juvenile castrated male Duroc swine were received and handled according to the facility standard operating procedures under an animal care and use program accredited by the Association for Assessment and Accreditation of Laboratory Animal Care International and Public Health Service Animal Welfare assured until the time of the experiment.

Totally, three animals were used in the work described. The number of subjects were determined based on a convenience sample. At the time of surgery, animals weighed between 68 kg and 78 kg. Animals were anesthetized with a combination of ketamine and xylazine that were delivered intramuscularly. Animals were intubated, maintained on isoflurane, placed on a warming blanket, and ventilated. Body hair was clipped and the skin was prepped with chlorhexidine gluconate scrub. An esophageal probe was placed for monitoring of cardiac rate and rhythm as well as core body temperature. An oral gastric tube was placed for gastric drainage as per the institution's Institutional Animal Care and Use Committee protocol. A double lumen central venous catheter was placed in the internal jugular vein for monitoring of central venous pressure and delivery of normal saline. Non-invasive blood pressure, peripheral oxygen saturation, end-tidal carbon dioxide level, and peak inspiratory pressure were also monitored throughout course of time in the operating room.

A mid-line incision was made from the xiphoid process to just inferior to the penis to gain entry into the abdomen. Two small incisions were made in each abdominal lateral wall to allow passage of pressure-transducing catheters. Twenty-five catheters total were introduced into the abdomen, divided between these two holes (Fig. 1). Small Styrofoam discs were secured to the ends of each catheter to prevent shifting of catheter locations after placement within the abdomen. Catheters were intra-abdominally located as diagrammed in Figure 2 and described in Table 1. After placement of catheters, these were secured as a group to the skin entry site with suture and an occlusive dressing to prevent air leak on negative pressure initiation.

The ABTHERA system (Kinetic Concepts, Inc, San Antonio, TX) consists of a fenestrated plastic drape containing strips of granular foam sponge which is meant to be positioned over the abdominal viscera, a perforated granular foam sponge meant to be positioned at the level of fascia and skin, an occlusive adhesive drape to create a seal and allow for the establishment of negative pressure, as well as suction tubing with an adhesive connection site to transfer negative pressure from the vacuum machine to the dressing system (Fig. 3).

The laparotomy incision was closed with 0-0 Prolene suture (Ethicon Endosurgery, Inc, Somerville, NJ) and baseline pressure readings were obtained before the insertion of ABTHERA dressings or initiation of negative pressure. After baseline pressure readings were obtained, the abdomen was re-opened and the ABTHERA Fenestrated Visceral Protective Layer and sponge were applied with accompanying occlusive dressings. Again, baseline pressure readings were obtained before the initiation of negative pressure. The ABTHERA

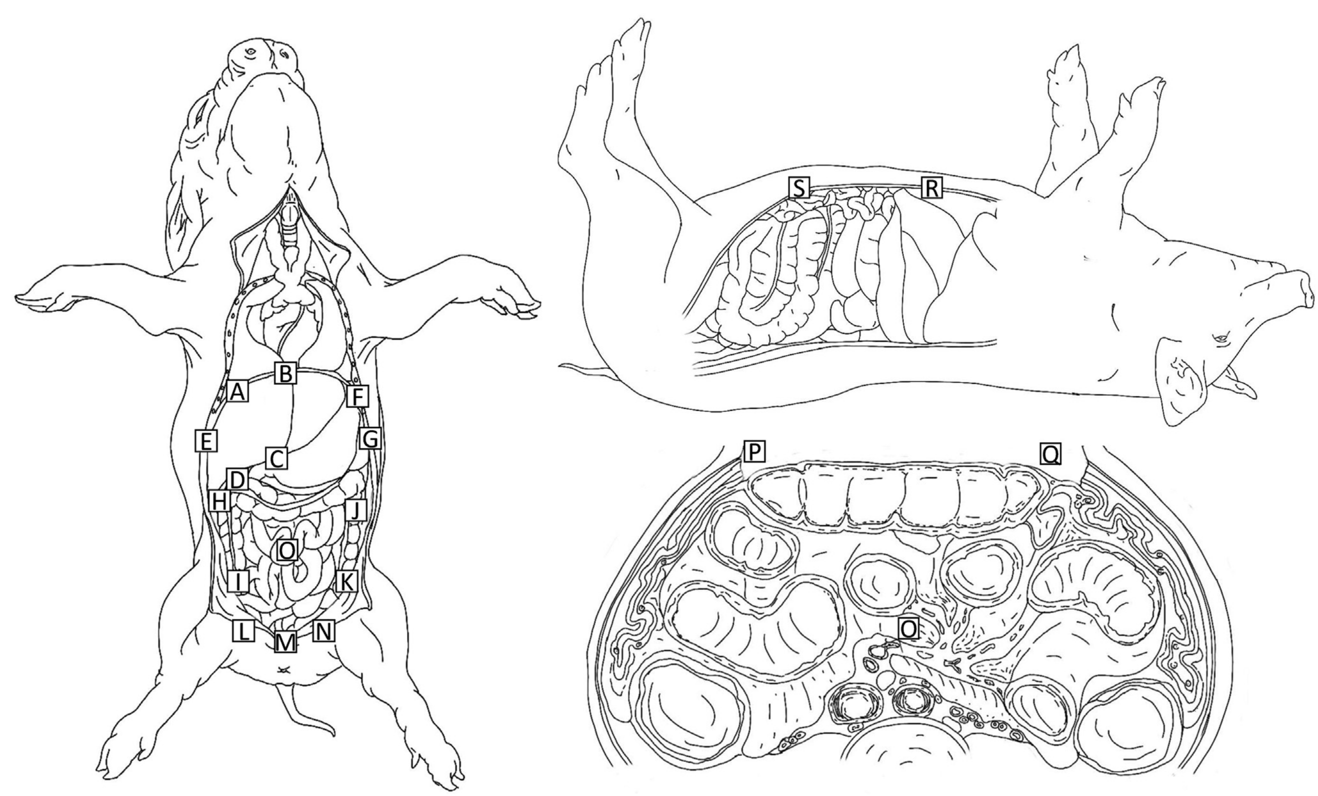

Fig. 2 – Diagram of locations of pressure-transducing catheters within the abdomen. Descriptions of these locations in Table 1.

Table 1 – Catheter locations by letter and description. Corresponds to Figure 2.

Diagrammed catheter letter	Descriptive location
A	Superior right liver, adjacent to segment 8
B (two catheters)	Superior mid-liver, adjacent to segments 4 and 8
C (two catheters)	Inferior mid-liver, adjacent to segments 4 and 5
D	Inferior right liver, adjacent to segments 5 and 6
E	Right posterior lateral liver, adjacent to segment 7
F	Left sub-diaphragmatic, superior to spleen
G	Posterior to spleen
H	Right superior paracolic gutter
I	Right inferior paracolic gutter
J	Left superior paracolic gutter
K	Left inferior paracolic gutter
L (two catheters)	Right pelvis
M (two catheters)	Mid pelvis
N (two catheters)	Left pelvis
O (two catheters)	Root of small bowel mesentery
P	Under right abdominal wall
Q	Under left abdominal wall
R	Upper midline abdominal wall
S	Lower midline abdominal wall

dressing was then connected to suction and intra-abdominal pressure measurements were monitored during the period of negative pressure application with stepwise increasing intensity. Settings employed were: 0 mmHg, −75 mmHg, −100 mmHg, −125 mmHg, −150 mmHg, −175 mmHg, and finally −200 mmHg, maintaining each pressure level for a duration of 5 min. Central venous pressure, oxygen saturation, end tidal carbon dioxide level, non-invasive blood pressure, and heart rate were all monitored during this process using a VetSpecs SM100 Patient Monitor (VetSpecs, Canton, GA). Peak inspiratory pressure was measured using the compartment pressure transduction system (CPTS). After

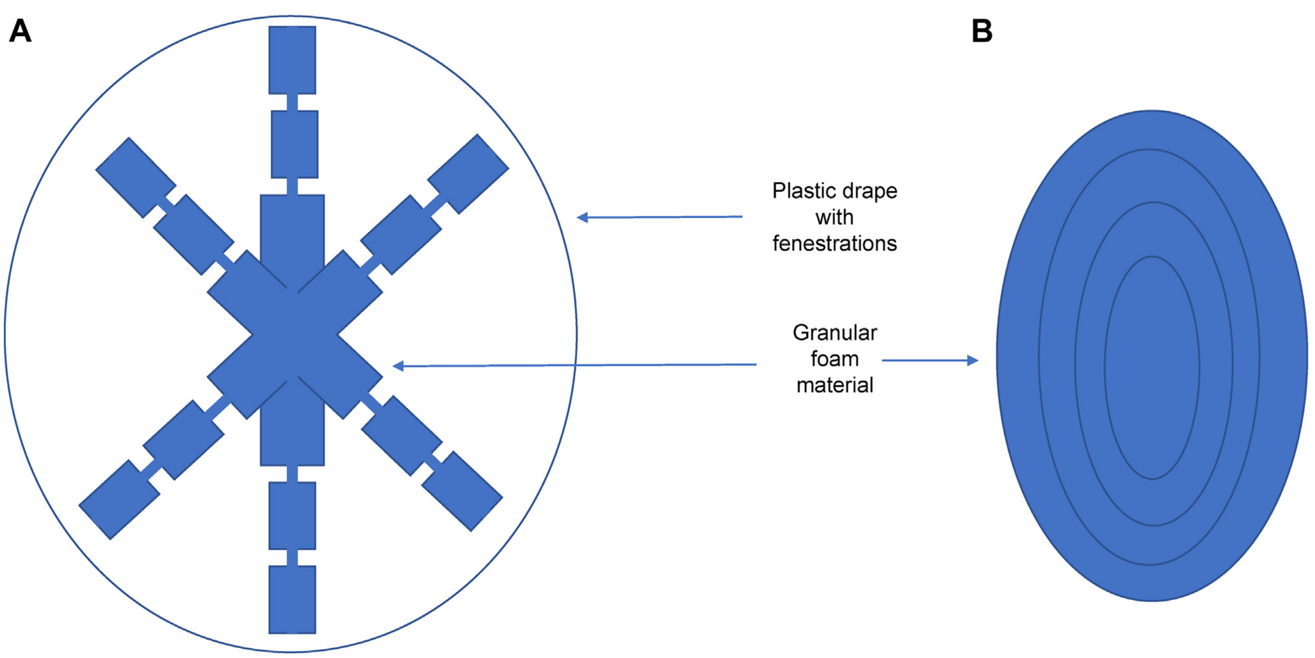

Fig. 3 – Abdominal components of the ABTHERA NPWT open abdomen dressing system include a bilayered, fenestrated plastic drape encasing connected channels of blue granular foam material (A), meant to cover the intraabdominal viscera and protect them from a perforated, ovoid, blue granular foam material (B), which is placed at the level of the skin and abdominal wall fascia.

A

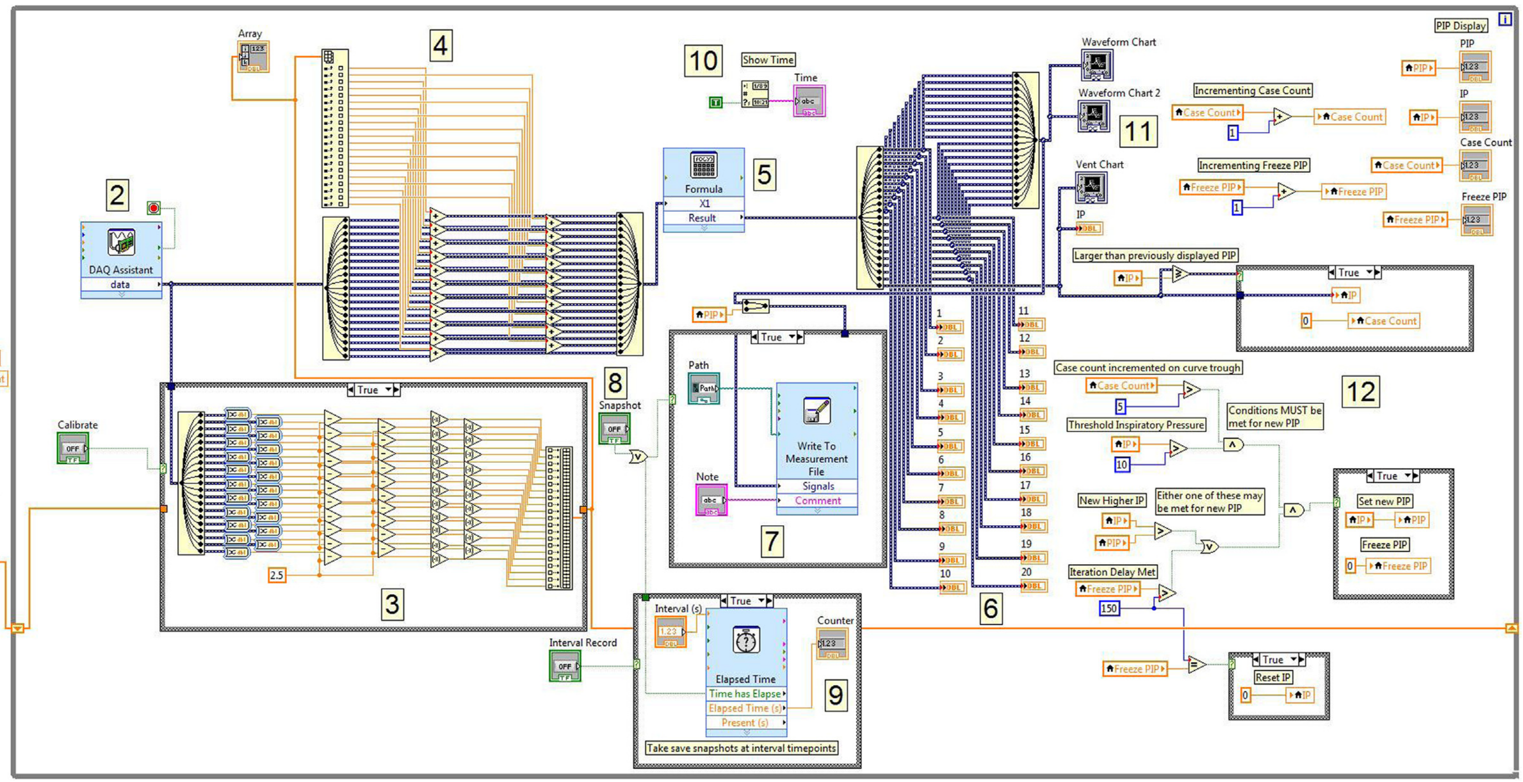

Fig. 4 – Compartment pressure transduction system circuit diagram (A). Compartment pressure transduction system transducer setup (B).

B

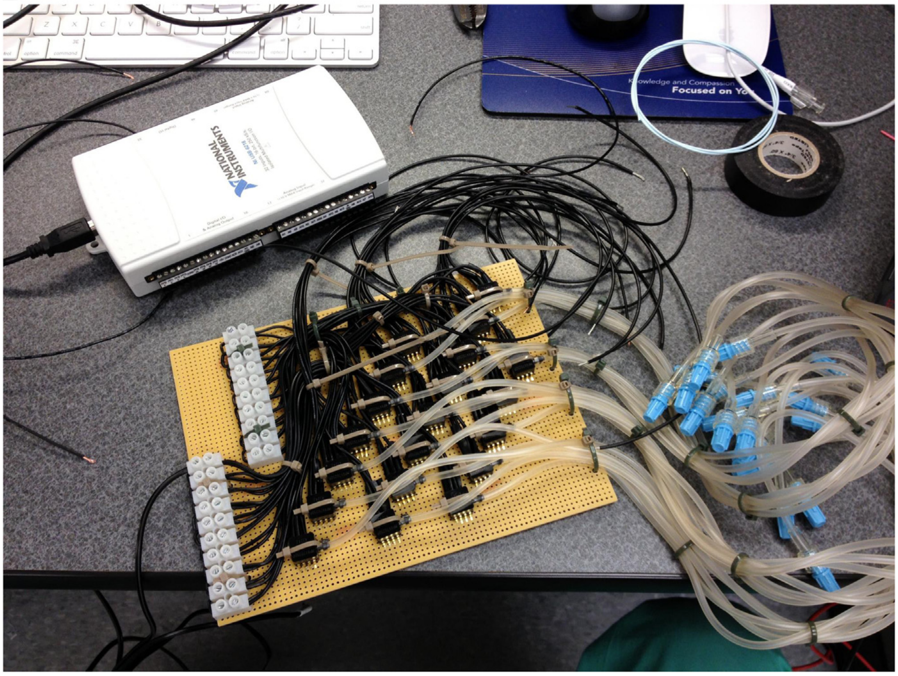

Fig. 4 – Continued.

achieving an NPWT seal at −200 mHg and collecting the corresponding measurements, negative pressure delivery was halted, and the abdomen was once again opened. Ten laparotomy pads were used to pack the abdomen in the perihepatic and perisplenic regions. The ABTHERA Fenestrated Visceral Protective Layer and sponge were again applied with accompanying occlusive dressings and negative pressure was delivered in the same stepwise increasing fashion as prior to packing. Intra-abdominal pressure measurements and vital signs were again collected as above.

Compartment pressure transduction system

The abdominal CPTS quantifies pressure in difficult to access locations by relaying through catheters to externally housed transducers (Fig. 4). These transducers then provide an analog signal to a data acquisition device for digital conversion. The data acquisition device interfaces with a computer responsible for calibrating, recording, and displaying the signals externally to a user.

The CPTS is composed of five individual components:

1. Twenty-five angiographic catheters.
2. Twenty-five polypropylene luer connections.
3. Twenty-five individual transducers.
4. Operational amplification system.
5. Data acquisition device.

The device is capable of measuring pressures in the range of −25 to 25 kPa (−187 to 187 mmHg) with a maximum error of ± 5%. Data capture may be accomplished at any specified resolution upto 250,000 captures/s.

Data analysis

Data were collected from the CPTS at a rate of 1000 captures/s and averaged for each 5-min period of a given negative pressure setting. This was completed for each of three animals. The pressure value obtained at each NPWT benchmark

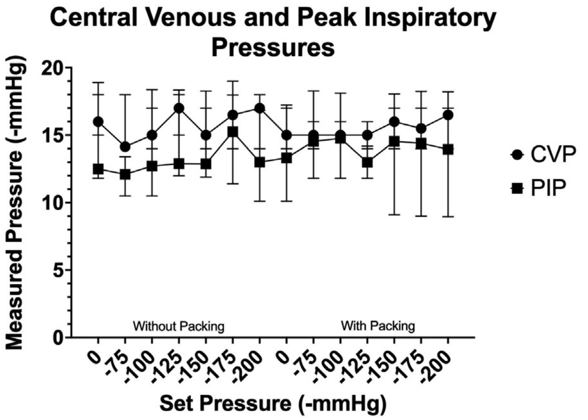

Fig. 5 – Central venous pressure ranged from 14 mmHg to 18 mmHg amongst all three animals for the duration of the experiment and variation within each animal was 3 mmHg or less, regardless of VAC pressure setting. Peak inspiratory pressure ranged from 9 mmHg to 19 mmHg amongst all three animals for the duration of the experiment and variation within each animal was 3 mmHg or less, regardless of VAC pressure setting. Data points graphed as medians with ranges.

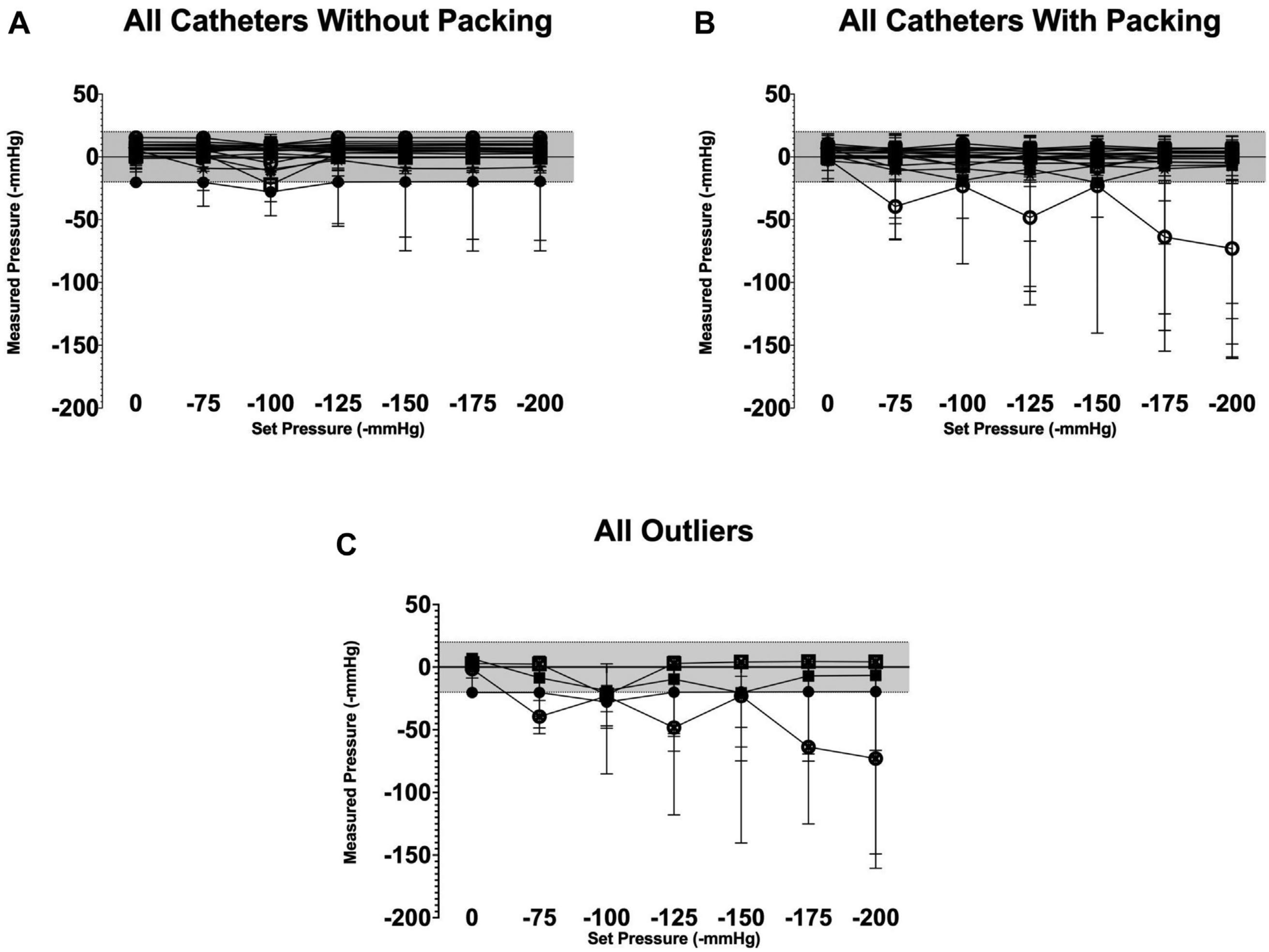

Fig. 6 – The majority of catheters' measured pressure remained within the baseline range of −20 mmHg and 20 mmHg (shaded) throughout the course of the experiments. Error bars represent minimum to maximum ranges. (A) Median readings of all catheter locations prior to insertion of laparotomy pad packing with error bars representing ranges. (B) Median readings of all catheter locations after the insertion of laparotomy pad packing. (C) Four catheters recorded median pressure measurements outside the baseline range of −20 mmHg and 20 mmHg.

Table 2 – Catheters with median pressure measurements (reported in mmHg with minimum, maximum) outside the baseline range (−20 mmHg to 20 mmHg), shown in bold. Corresponds to Figure 6C.

Catheter letter and location/Set VAC pressure	(A) Superior right liver – no packing	(B) Superior mid-liver – packed	(R) upper midline abdominal wall – packed	(S) lower midline abdominal wall – no packing
0	**−20.3 (−24.5, 0.5)**	6.8 (−1.5, 8.7)	−1.5 (−2.2, 5.5)	2.9 (−8.8, 6.9)
−75	**−20.2 (−39.3, 0.6)**	−8.5 (−53.2, 8.8)	**−39.5 (−48.6, 3.9)**	2.5 (−26.7, 5.7)
−100	**−27.9 (−35.6, −20.2)**	−18.8 (−85.1, −14.7)	**−23.1 (−48.8, 2.6)**	**−22.1 (−46.9, 2.7)**
−125	−20.0 (−55.2, 0.7)	−9.6 (−117.9, 8.8)	**−48.2 (−67.0, 2.3)**	2.9 (−53.1, 3.7)
−150	−19.9 (−74.7, 0.6)	**−20.5 (−140.4, −7.4)**	**−23.0 (−48.0, 1.9)**	4.1 (−63.8, 4.1)
−175	−19.7 (−75.0, 0.7)	−7.1 (−125.0, −7.4)	**−63.7 (−69.4, 1.7)**	4.5 (−65.6, 4.8)
−200	−19.6 (−74.9, 0.6)	−6.6 (−149.0, 9.1)	**−73.0 (−160.5, 1.4)**	4.3 (−66.4, 4.4)

Table 3 – To further analyze the conveyance of negative pressure to different intraabdominal areas, catheters were grouped into three regions: Abdominal Wall, Perihepatic Perisplenic, and Deep Abdomen. Corresponds to Figure 7.

Region	Diagrammed catheter letter	Descriptive location
Perihepatic perisplenic	A	Superior right liver, adjacent to segment 8
	B (two catheters)	Superior mid-liver, adjacent to segments 4 and 8
	C (two catheters)	Inferior mid-liver, adjacent to segments 4 and 5
	D	Inferior right liver, adjacent to segments 5 and 6
	E	Right posterior lateral liver, adjacent to segment 7
	F	Left sub-diaphragmatic, superior to spleen
	G	Posterior to spleen
Deep abdomen	H	Right superior paracolic gutter
	I	Right inferior paracolic gutter
	J	Left superior paracolic gutter
	K	Left inferior paracolic gutter
	L (two catheters)	Right pelvis
	M (two catheters)	Mid pelvis
	N (two catheters)	Left pelvis
	O (two catheters)	Root of small bowel mesentery
Abdominal wall	P	Under right abdominal wall
	Q	Under left abdominal wall
	R	Upper midline abdominal wall
	S	Lower midline abdominal wall

setting (0 mmHg, −75 mmHg, −100 mmHg, −125 mmHg, −150 mmHg, −175 mmHg, and −200 mmHg, with and without laparotomy pad packing) was recorded for all three animals and an average value with $n = 3$ subjects, was calculated for each setting. The normal baseline pressure range of each catheter before initiation of NPWT was observed over all data points and identified to fall between the range of −20 mmHg and 20 mmHg. These were identified as the normal baseline range of each catheter. Values were graphed in individualized and regionalized fashions as in Figures 6 and 7 with data points representing median values and error bars representing minimum to maximum ranges. Values that fell outside of the identified baseline pressure level range of −20 mmHg to 20 mmHg were identified as potentially clinically significant. Individual and regionalized values at each set pressure level were compared to baseline and analyzed by Kruskall-Wallis test, with statistical significance set at $P < 0.05$.

Results

Central venous pressure ranged from 14 mmHg to 18 mmHg amongst all three animals for the duration of the experiment and variation within each animal was 3 mmHg or less, regardless of NPWT pressure setting (Fig. 5). Peak inspiratory pressure ranged from 9 mmHg to 19 mmHg amongst all three animals for the duration of the experiment and variation within each animal was 3 mmHg or less, regardless of NPWT pressure setting (Fig. 5). Similarly, there was no correlation

Table 4 – Regions with median pressure measurements (reported in mmHg with minimum, maximum). No median pressure measurements were outside the baseline range (−20 mmHg to 20 mmHg). Corresponds to Figure 7.

Catheter region/Set VAC pressure	Abdominal wall – no packing	Abdominal wall – packed	Perihepatic perisplenic – no packing	Perihepatic perisplenic – packed	Deep abdomen – no packing	Deep abdomen – packed
0	4.2 (−19.5, 7.6)	1.1 (−17.3, 11.9)	6.0 (−24.5, 15.6)	3.4 (−5.5, 18.4)	7.3 (−21.3, 17.7)	3.3 (−5.5, 18.4)
−75	0.6 (−26.7, 7.7)	−8.9 (−66.1, 11.0)	5.7 (−39.3, 15.5)	1.1 (−53.1, 18.5)	7.3 (−20.9, 17.9)	1.1 (−53.1, 18.5)
−100	−9.9 (−46.9, 7.6)	−9.4 (−48.8, 11.0)	5.1 (−35.6, 15.6)	−0.1 (−85.1, 17.0)	8.7 (0.3, 17.9)	−0.1 (−85.1, 17.0)
−125	1.1 (−53.1, 7.6)	−9.5 (−103.2, 11.0)	5.8 (−55.2, 15.7)	1.1 (−117.9, 15.2)	7.4 (−20.2, 17.8)	1.1 (−117.9, 15.2)
−150	1.4 (−63.8, 7.4)	−7.1 (−48.0, 10.7)	6.3 (−74.7, 15.7)	−0.6 (−140.4, 14.4)	7.2 (−20.0, 17.8)	−0.6 (−140.4, 14.4)
−175	1.4 (−65.6, 8.1)	−6.7 (−138.2, 11.1)	6.4 (−75.0, 15.8)	1.3 (−125.0, 14.0)	7.4 (−19.8, 17.8)	1.3 (−125.0, 14.0)
−200	1.2 (−66.4, 8.8)	−6.0 (−160.5, 12.1)	6.4 (−74.9, 15.8)	1.4 (−149.0, 13.6)	7.0 (−19.8, 17.8)	1.4 (−149.0, 13.6)

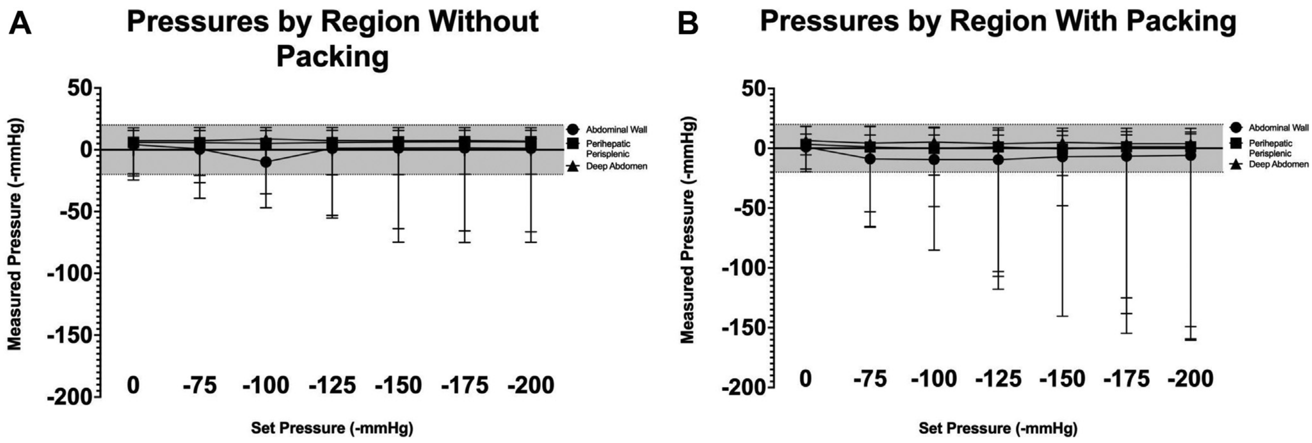

Fig. 7 – (A) When catheters are grouped by the regions described in Table 3, there is no significant change in intraabdominal pressure at any NPWT setting with or without intraabdominal packing. After the addition of intraabdominal packing (B), the catheters situated at the abdominal wall show some intensified negative pressure readings, though these still do not achieve the same negative pressure as set by the NPWT machine. Error bars represent minimum to maximum ranges.

between NPWT pressure setting and changes in heart rate, non-invasive blood pressure, respiratory rate, end tidal carbon dioxide saturation, oxygen saturation, or body temperature for any of the three animals (data not shown).

Baseline catheter pressure measurements prior to the initiation of negative pressure ranged from −20 mmHg to 20 mmHg in all animals and all catheter locations. This was the same whether the abdomen was packed with laparotomy pads or not (Fig. 6A and B). Most catheters recorded pressures within this baseline range for the entirety of the experiments. Four catheter locations measured median pressure levels outside the baseline pressure range, depicted in Figure 6C and Table 2. The largest divergence from baseline pressure measurements occurred in catheter location the R (Fig. 2), situated at the upper midline abdominal wall, with packing in place. At a set pressure of -200 mmHg, the catheters at this location measured a median pressure of −73.0 mmHg (range −160.5 to 1.4). Catheter pressure values at each set pressure level were compared to baseline and no catheter location achieved a statistically significant change from baseline pressure. Of the catheters that diverged from the baseline pressure measurements, no catheter ever measured a pressure equal to or negative more than that of the set negative pressure of the NPWT device.

To further analyze the conveyance of negative pressure to different intra-abdominal areas, catheters were grouped into three regions: Abdominal Wall, Perihepatic/Perisplenic, and Deep Abdomen. Catheter locations corresponding to each region are represented in Table 3.

When catheters are grouped by the above three regions, there is no clinically or statistically significant change in intra-abdominal pressure at any NPWT setting prior to the addition of intra-abdominal packing. After the addition of intra-abdominal packing, the catheters situated at the abdominal wall show some intensified negative pressure readings, though these do not achieve the same negative pressure as set by the NPWT machine and again do not achieve statistical significance. All median values remained within the −20 mmHg and 20 mmHg range (Table 4, Fig. 7).

Discussion

The pressure environment within the abdomen during treatment with NPWT is not well-understood. This study aimed to clarify the effect of NPWT with the ABTHERA system on the intra-abdominal pressure levels of various locations within an open abdomen swine model. When all components of the dressing system were used (plastic drape as well as fascia-level sponge), deep spaces within the abdomen were consistently unaffected by the application of or change in level of negative pressure. In addition, placement of laparotomy pad packing materials around abdominal viscera as may be done in various surgical scenarios, does not appear to convey negative pressure when the system is used. Those areas which did show changes in pressure were most often superficial and associated with sensors adjacent to NPWT sponge locations. This may support the concerns of clinicians who worry about intra-abdominal negative pressure conveying to bowel wall with associated development of visceral malperfusion, serosal trauma, or enteric fistulae,[1,9-11] but, seems to be relevant only when a protective layer of plastic does not separate the wall of intra-abdominal viscera from the sponge attached to negative pressure.[17]

The majority of pressure-sensing catheters did not vary from their baseline readings with the application of increasing levels of negative pressure, with or without intra-abdominal packing. Those few areas which did measure a change were most often at an area adjacent to the abdominal wall. These catheter locations were superficial to the ABTHERA Fenestrated Visceral Protective Layer provided as part of an ABTHERA system (Figs. 2 and 3). This may highlight the protective effect of the plastic drape component of this NPWT system in that the negative pressure delivered at the fascia-level sponge is not in direct contact with the viscera beneath the drape. It is worth noting, however that even the catheters sensing a pressure change near the abdominal wall did not register a change to the magnitude of the programmed pressure on the NPWT machine. When the abdomen was divided into regions (abdominal wall, deep abdomen, and perihepatic/perisplenic), no regions showed a trend of any significant change in abdominal pressure from baseline (−20 mmHg to 20 mmHg) readings.

Our data also do not suggest an important physiologic impact from NPWT. There was no effect on the central venous pressure or peak inspiratory pressure of any animal, regardless of negative pressure setting or intra-abdominal packing. Similarly, porcine heart rate, non-invasive blood pressure, peripheral oxygen saturation, end-tidal carbon dioxide saturation, and body temperature were not affected by the application of abdominal negative pressure wound therapy. A pulmonary arterial catheter was not utilized in this study, though it could provide an additional useful data, especially if the experiment was repeated in a hemorrhagic shock model.

Limitations to this study include the small number of animals used and their physiologically normal status. The goal of this study was specifically to investigate the role of NPWT on the intra-abdominal pressure environment and whether NPWT itself changed vital signs within the animals studied. A shock environment was not modeled. We found that NPWT itself does not neither change the measured pressure within the abdomen nor vital signs, which has not previously been shown. Often, open abdominal NPWT is used in damage control scenarios with critically ill patients who may not reflect the hemodynamics observed in this study. Specific features of intra-abdominal organ perfusion were also not investigated. Subtle hemodynamic impacts might be more apparent on physiologically stressed subjects and would be valuable to investigate in future iterations of this work.

Conclusions

NPWT induces little change in intra-abdominal pressure, except in superficial locations in packed abdomens and does not appear to cause hemodynamic or other vital sign changes in this pilot study using a porcine open abdomen model. While NPWT may play an important role in fluid scavenging and fascial tensioning, there are likely to be few benefits or drawbacks specifically related to negative abdominal pressure levels in the deep abdomen.

Author Contributions

TET prepared and submitted the manuscript and participated in the animal work. NJP built and managed the system for intraabdominal pressure monitoring, participated in the animal work, and contributed to manuscript editing. JWS participated in the animal work and contributed to manuscript editing. JAS conceptualized the project, participated in the animal work and contributed to manuscript editing.

Disclosure

None declared.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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