Modelling and Measuring Intra-abdominal Hypertension in the Deployed Environment

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INTRODUCTION

Large scale combat operations (LSCO) are expected to place unprecedented demands on military medical logistics, potentially limiting the availability of blood products for damage control resuscitation. Under these conditions, providers may be forced to rely on large volume crystalloid or synthetic fluid resuscitation, increasing the risk of intra-abdominal hypertension (IAH) and progression to abdominal compartment syndrome (ACS).

IAH is associated with impaired respiratory mechanics, reduced venous return, decreased renal perfusion, intestinal ischemia, and ultimately multi-organ failure if left untreated. Early recognition is therefore critical, yet current gold standard monitoring using transvesical bladder pressure requires urinary catheterization, sterile equipment, and intermittent measurements that may be impractical in prolonged field care or other austere environments.

Continuous, minimally invasive pressure monitoring could provide earlier detection of rising intra-abdominal pressure (IAP) and improve triage and evacuation decisions. The objective of this study was to develop a reproducible cadaveric model of severe IAH and evaluate the performance of the MY01 solid state MEMS pressure sensor as a potential dual-use technology for continuous IAP monitoring.

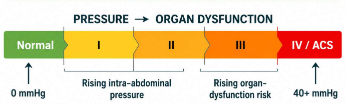
CLINICAL BACKGROUND

IAH is defined by the World Society of the Abdominal Compartment Syndrome (WSACS) as sustained intra-abdominal pressure ≥12 mmHg. Abdominal compartment syndrome occurs when intra-abdominal pressure exceeds 20 mmHg in the presence of new organ dysfunction. Untreated ACS is associated with mortality rates approaching 40–70%, highlighting the importance of early recognition and intervention.

INTRA-ABDOMINAL PRESSURE GRADING

WSACS GRADING OF IAH

Grade	IAP (mmHg)
Grade I	12–15
Grade II	16–20
Grade III	21–25
Grade IV	>25
ACS	>20 + new organ dysfunction



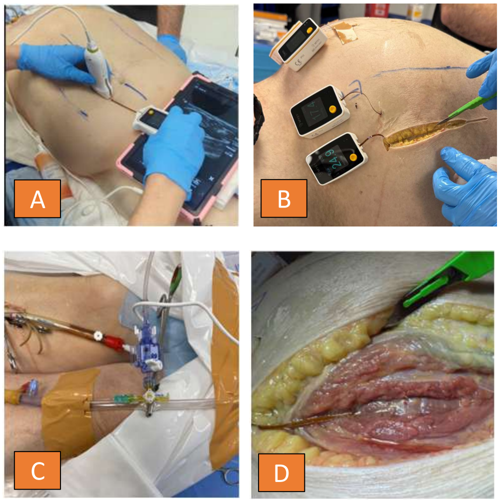
HYPOTHESIS

We hypothesized that (1) a reproducible cadaveric model could reliably generate clinically significant IAH, (2) the MY01 Continuous Compartment Pressure Monitor would accurately track dynamic changes in IAP compared with transvesical bladder pressure, and (3) determine sensor placement within the abdominal wall, to determine superior agreement with the clinical reference standard.

METHODS

A fresh-frozen 67-year old male cadaver (BMI 25.1) was instrumented using a carotid artery cutdown connected to an infusion pump and fluid reservoir to generate progressively increasing intra-abdominal pressure. Transvesical bladder pressure (TVBP), measured by fluid column manometry, served as the clinical reference standard. Six MY01 Continuous Compartment Pressure Monitor (CCPM) (MY01 Inc., Montreal, Canada), measuring compartment pressure with a solid-state Micro-Electro-Mechanical Systems (MEMS) pressure sensor, were inserted under ultrasound guidance into predefined abdominal wall tissue planes, including the subcutaneous tissue, rectus abdominis, external oblique, internal oblique, and bilateral transversus abdominis muscles. Controlled fluid infusion was continued until sustained TVBP exceeded 50 mmHg, establishing a cadaveric model of severe IAH. Sensor measurements were compared with corresponding TVBP measurements throughout the infusion protocol. Agreement between each sensor and the reference standard was assessed using Bland–Altman analysis, while linear association was evaluated using Pearson correlation coefficients. Analyses were performed separately for each anatomical layer to compare measurement agreement across sensor depths.

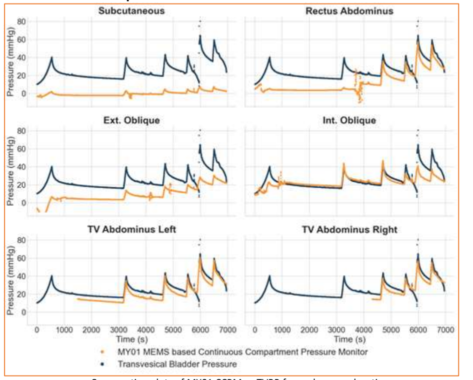
EXPERIMENTAL MODEL DEVELOPMENT



Experimental model development. (A) Ultrasound-guided placement of MY01 CCPM into predefined abdominal wall tissue planes. (B) Experimental setup demonstrating a markedly distended abdomen following induction of severe IAH. (C) Carotid artery cutdown with controlled fluid infusion circuit used to progressively elevate intra-abdominal pressure. (D) Dissection confirming sensor trajectory and anatomical placement within the abdominal wall.

RESULTS

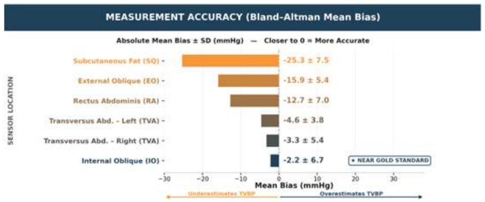
The experimental model reproducibly generated severe IAH, achieving sustained bladder pressures exceeding 50 mmHg following six infusion cycles totaling 52.5L. All MY01 CCPM demonstrated the ability to detect dynamic changes in IAP throughout the infusion protocol. Pearson correlation coefficients ranged from 0.73 to 0.93 across anatomical locations, indicating strong temporal agreement with transvesical bladder pressure. Although superficial sensors exhibited relatively high correlation, they consistently underestimated true intra-abdominal pressure. Measurement accuracy generally improved with deeper sensor placement, with the internal oblique sensor demonstrating the smallest mean bias (-2.2 ± 6.7 mmHg), providing the closest agreement with the clinical reference standard. All tissue planes captured respiratory and transient physiologic pressure fluctuations with high temporal agreement despite differences in absolute pressure bias.



Comparative plots of MY01 CCPM vs TVBP for each sensor location.

Sensor Site	Correlation (r)	Bias vs. TVBP (mmHg)
Subcutaneous tissue (SQ)	0.880	−25.3 ± 7.5
Rectus abdominis (RA)	0.812	−12.7 ± 7.0
External oblique (EO)	0.825	−15.9 ± 5.4
Internal oblique (IO)	0.727	−2.2 ± 6.7
Transversus abdominis (TA) - Left	0.934	−4.6 ± 3.8
Transversus abdominis (TA) - Right	0.867	−3.3 ± 5.4

Correlation (r) and bias (mean ± SD) between MY01 CCPM and transvesical bladder pressure (TVBP) at six abdominal sensor sites. The transversus abdominis showed the strongest agreement with TVBP, supporting it as the preferred site for intra-abdominal pressure monitoring.



Bland–Altman mean bias (± SD) between MY01 CCPM and Transvesical bladder pressure (TVBP) by sensor location. The internal oblique demonstrated the highest accuracy (bias: −2.2 ± 6.7 mmHg), while subcutaneous placement showed the greatest underestimation.

DISCUSSION

These findings demonstrate that abdominal wall tissue depth influences pressure transmission and measurement accuracy. While superficial tissues tracked pressure trends, local tissue compliance likely attenuated absolute pressure measurements. Sensors positioned within deeper muscular compartments more closely approximated intraperitoneal pressure, suggesting that the internal oblique represents an optimal balance between measurement accuracy and minimally invasive placement. The present cadaveric model also demonstrates a reproducible experimental platform for evaluating emerging pressure monitoring technologies under conditions representative of severe resuscitation induced IAH.

In prolonged field care, delayed evacuation, limited monitoring capabilities, and constrained personnel increase the risk that IAH will progress undetected until advanced organ dysfunction has occurred. A compact, minimally invasive MEMS-based monitoring system may provide continuous IAP surveillance during prolonged transport and extended casualty management, improving situational awareness, supporting damage control resuscitation, informing triage and evacuation priorities, and enabling earlier recognition of patients at risk for abdominal compartment syndrome.

CONCLUSIONS

This study demonstrates the feasibility of continuous IAP monitoring using a minimally invasive solid-state MEMS pressure sensor in a cadaveric model of severe intra-abdominal hypertension. While all sensor locations tracked dynamic pressure changes, agreement with the transvesical reference improved with increasing tissue depth, with the internal oblique demonstrating the closest agreement. These findings suggest that implantation depth is a key determinant of measurement accuracy and should guide future device optimization. In prolonged field care, delayed evacuation, and other austere environments, where conventional bladder pressure monitoring is impractical, a compact MEMS-based platform could provide continuous IAP surveillance, improving physiologic awareness and supporting damage control resuscitation, triage, and evacuation decisions. Although further validation in perfused cadaveric and in vivo models is needed, this technology has the potential to address a critical monitoring gap in future combat and austere care settings.

CLINICAL TRANSLATION

A minimally invasive MEMS-based platform could provide continuous intra-abdominal pressure monitoring from the point of injury through prolonged evacuation. This capability may improve physiologic awareness, support damage control resuscitation, aid triage and evacuation decisions, and enable earlier detection of abdominal compartment syndrome before irreversible organ injury develops.