ORIGINAL ARTICLE

Comparison of the Kron technique and digital manometry for measuring intra-abdominal pressure in emergency department patients diagnosed with ileus

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ABSTRACT

BACKGROUND: Numerous measurement techniques for intra-abdominal pressure have been explored, with the Kron Technique established as the gold standard. Despite its prominence, the search for alternative methods persists due to its lengthy application time, the requirement for additional equipment, and overall impracticality. This study investigated a quicker, more accessible method for effective intra-abdominal pressure measurement in the emergency department. It aimed to compare intra-abdominal pressure measurements in patients diagnosed with ileus using a digital manometer and the Kron Technique.

METHODS: Conducted from October 2022 to February 2023, this single-center, prospective, single-blind method comparison study involved patients diagnosed with ileus at a tertiary emergency department. Intra-abdominal pressure was measured using both the Kron Technique and a digital manometer by separate practitioners blinded to the study results.

RESULTS: The study included 30 patients. No statistically significant difference was observed in the intra-abdominal pressure measurements between the two methods ($p<0.237$). A very strong correlation existed between the two methods (Spearman's Rho = 0.998). Bland-Altman analysis showed a bias value of 0.091 mmHg for the digital manometer, with upper and lower agreement limits of -0.825 and 1.007 mmHg, respectively. The measurement time was significantly shorter with the digital manometer than with the Kron Technique (15 vs. 390.5 seconds; $p<0.001$).

CONCLUSION: We believe that the intra-abdominal pressure measurement technique using a digital manometer is a method that can be effectively employed by healthcare professionals in emergency departments. This technique offers ease of use, requires minimal equipment, provides rapid results, and delivers reliable measurement values compared to the Kron Technique.

Keywords: Abdominal cavity; manometry; ileus; emergency department.

INTRODUCTION

Intra-abdominal pressure (IAP) is defined as the stable pressure within the abdominal cavity. It can be influenced by a variety of factors, including physiological aspects such as diaphragm movements, pregnancy, and coughing, as well as mechanical conditions like tumors, ascites, trauma, and ileus, which can increase the volume in the intra-abdominal region. Furthermore, pathological conditions that impair intestinal function and lead to adynamia can also affect IAP.[1,2]

Elevated IAP can lead to a clinical condition known as Abdom-

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inal Compartment Syndrome (ACS), characterized by multiple organ failure and associated with high mortality rates.[3]

In individuals without underlying health issues, IAP typically ranges from 0 to 5 mmHg. An IAP exceeding 5 mmHg is defined as intra-abdominal hypertension, and if the pressure rises above 20 mmHg, resulting in newly developing organ failure, it is diagnosed as Abdominal Compartment Syndrome.[1]

Elevated IAP is well-documented to significantly increase mortality and morbidity. Therefore, early identification of high-risk patients is crucial for effective detection and management of elevated IAP.[4] The initial assessment of these patients in emergency departments is critical for early diagnosis and treatment.

Over the years, numerous methods have been employed for IAP measurement. However, the intravesical 'Kron Technique' is widely recognized as the gold standard.[1,5]

In our study, we aimed to compare the Kron Technique, a complex but gold-standard method, with IAP measurement using a digital manometer. We believe that the latter offers a simpler and faster approach to pressure measurement. To the best of our knowledge, this specific comparison has not been explored in existing literature.

MATERIALS AND METHODS

The study was conducted at the Emergency Medicine Department of a tertiary care hospital from October 30, 2022, to February 22, 2023. It was designed as a single-center, prospective, single-blind, method comparison study. Ethical approval was obtained from the local ethics committee. This trial was registered on clinicaltrials.gov (NCT06338813). Participants included patients over 18 years of age diagnosed with ileus, confirmed by radiological imaging (radiography and computed tomography).

Exclusion Criteria:

- Patients who underwent any decompressive procedure prior to measurement (Nasogastric catheter, enema).
- Patients who could not be catheterized for urine collection.
- Patients unable to be placed in the supine position due to conditions like advanced heart failure, kyphosis, etc.
- Uncooperative patients, including those with Alzheimer's, dementia, mental retardation, etc.
- Patients with morbid obesity (body mass index > 40 kg/m^2), ascites, or pregnancy.
- Patients who had undergone bladder surgery.
- Patients with neurogenic bladder.

In the literature, no study has measured IAP with a digital manometer in patients with ileus. In the study by Van Waes et al., the sample size was calculated based on the mean difference and standard deviation for IAP measurements. This analysis determined that a sample of at least 25 patients was necessary to achieve 80% power and maintain a Type I error rate of 5%, considering a mean difference of 1.6 and a standard deviation of 2.7 between measurements. To account for potential data losses, a total of 30 patients were planned to be included.[6]

Figure 1. Intrabdominal pressure measurement with kron technique.

Before the study commenced, the Kron Technique and IAP measurement using a digital manometer were demonstrated both didactically and practically to 4th-year Emergency Medicine residents. It was arranged for at least two of these residents to be continuously present on the monthly duty roster. When a patient meeting the inclusion criteria presented to the emergency department, the residents were separately invited to the bedside for measurements by the attending physician, who ensured they were unaware of each other's involvement. After the attending physician gathered the patient's information, the exclusion criteria were assessed. Once the patient was deemed eligible, the attending physician thoroughly explained the procedure and the study, obtaining informed consent verbally and in writing. Demographic information (age, gender) and medical history were recorded.

Measurements were performed with the patient in the supine position. A transurethral Foley catheter (16 Fr) was inserted by the attending physician under sterile conditions. IAP was

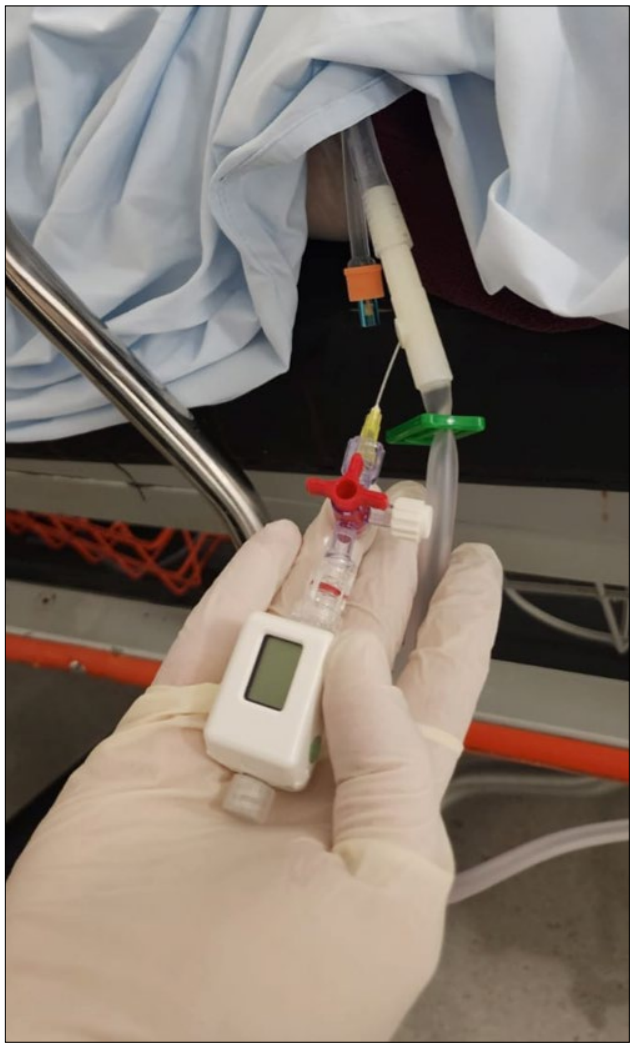

Figure 2. Intrabdominal Pressure Measurement with Compass Lumbar Puncture Pressure Transducer (Mirador Biomedical, Seattle, WA, USA).

measured using the 'Kron Technique.' The connection hose of the urine collection container was attached to the Foley catheter, and the hose was clamped after completely emptying the bladder's urine. (Fig. 1). The hose was clamped at the same location in both techniques to avoid measurement discrepancies. A sterile three-way tap was then attached to the urine sample port in the connection hose using a 20 gauge syringe needle. Through the three-way tap, 25 ml of sterile saline was injected into the bladder using a syringe. Subsequently, one end of the transducer interconnection cable was connected to the three-way tap, and the other end was connected to the bedside monitor (GE B40 V3 bedside monitor, Germany). Subsequently, the monitor was reset for pressure adjustments, and IAP was recorded in mmHg. Following this, a digital manometer was utilized for the next measurement, conducted by the second resident. The "Compass Lumbar Puncture Pressure Transducer" (Mirador Biomedical, Seattle, WA, USA) was employed as the digital manometer (Fig. 2). After completely emptying the bladder, the hose was clamped at the same location. A sterile three-way tap was attached to the urine sample port in the connection hose using a 20 gauge syringe needle. From the three-way tap, 25 ml of sterile saline was injected into the bladder with a syringe. The digital manometer was then connected to the three-way tap. The device was activated using the power button on the left side, and the IAP value displayed in cmH2O on the digital screen was noted. This measurement was converted to mmHg using the equation "1 cm H2O = 0.7355 mmHg." During these measurements, the patient's treatment plan continued without interruption.

The measurements were conducted by two separate residents, each blind to the study's other aspects and designated to one method to prevent bias. The results were placed in sealed envelopes with the patient's study number. The study concluded when the target number of patients was reached.

Statistical analyses were conducted using IBM SPSS (Statistical Package for the Social Sciences) Statistics for Windows, Version 20.0 (Armonk, NY: IBM Corp). Demographic data and frequency distributions were initially analyzed. Categorical data were expressed as sample numbers (n) and percentages (%), while continuous numerical data were represented as means, standard deviations, medians, and interquartile ranges.

The normality of continuous (numerical) data was assessed using the Shapiro-Wilk test and histogram graphs. Mean comparisons between two dependent groups were conducted using the Paired Samples t-test, and comparisons of medians were performed using the Wilcoxon or Sign test. To compare means between two independent groups, the Independent Samples t-test was employed.

For assessing the correlation between two numerical variables, we utilized the Spearman correlation test for non-normally distributed variables. For evaluating the primary outcome, an agreement analysis between the two tests was conducted using the Bland-Altman test. A significance level of $p<0.05$ was adopted for statistical significance.

RESULTS

Initially, 42 patients with ileus were considered for our study. Among them, 12 patients were excluded for various reasons, including morbid obesity (n=6), intubation (n=2), severe kyphosis (n=1), ascites (n=1), a history of bladder surgery (n=1), and an inability to insert a transurethral catheter (n=1). Our statistical evaluation was performed on the remaining 30 patients.

Demographic data, including height, weight, and medical history of the patients, are presented in Table 1. The median values for height and weight were 168 cm (Interquartile Range [IQR]: 160-178) and 75 kg (IQR: 68-79), respectively, with a median Body Mass Index (BMI) of 25.5 kg/m2 (IQR: 23.6-28.4).

Table 1. Demographic data, body mass index, and medical history of patients

	Number	Percentage (%)
Total Patients	30	100
Gender		
Male	17	56.7
Female	13	43.3
Age (Years)		
<65	18	60
65 and above	12	40
BMI (kg/m2)		
<25	15	50
25-30	11	36.7
30-40	4	13.3
Comorbidities		
Hypertension	7	23.3
Diabetes Mellitus	3	10
Malignancy	5	16.7
Liver Cirrhosis	1	3.3
Other	6	20
Surgical History		
Inguinal Hernia	3	10
Cancer Surgery	4	13.3
Cholecystectomy	4	13.3
Umbilical Hernia	3	10
Total Abdominal Hysterectomy	5	16.7
Other	5	16.7
Past Abdominal Surgery		
Yes	20	66.7

The median pressure value measured using the Kron Technique was 9.00 mmHg, while the digital manometer yielded a median value of 8.46 mmHg. Statistical analysis revealed no significant difference between the pressure measurements obtained with these two methods (p=0.237) (Table 2, Fig. 3).

The median time required for the Kron Technique was 390.5 seconds, compared to 15 seconds using the digital manometer, excluding the time for transurethral Foley catheter insertion. This difference was statistically significant (p<0.001), indicating that the digital manometer reduced the IAP measurement time (Table 2, Fig. 3).

Spearman's Rho analysis demonstrated a "very strong" correlation between pressure measurements obtained using the Kron Technique and the digital manometer (Spearman's rho = 0.998; p<0.001).

The agreement analysis between the Kron Technique and the digital manometer measurements for all patients showed that the bias line closely approximated zero (Fig. 4). The bias value was 0.091 mmHg (range: -0.084-0.266), indicating an acceptable difference between the two techniques and thus demonstrating their compatibility (Table 3).

DISCUSSION

Increased IAP can lead to critical conditions such as intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS), which directly affect the circulatory system and organs, potentially resulting in serious mortality and morbidity. These severe consequences can be mitigated by measuring IAP, particularly in high-risk patients, and by the early detection of IAH in the emergency department.[1,7]

Various methods have been explored for measuring IAP to

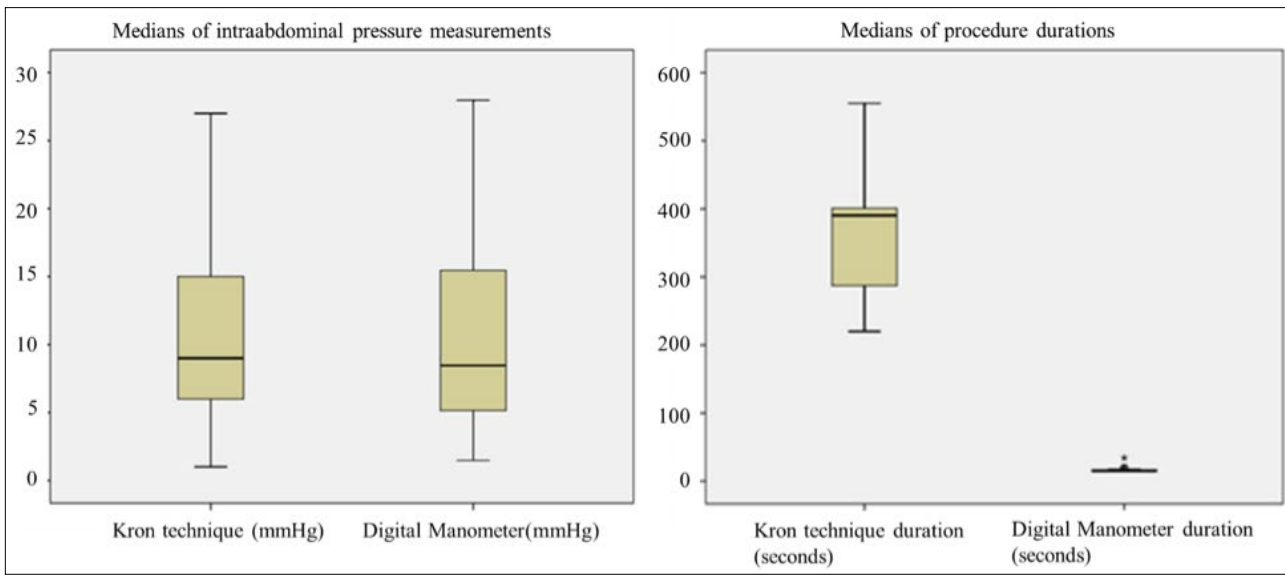

Figure 3. Median values of IAP measurements and application times.

Table 2. Comparison of intra-abdominal pressure (IAP) measurements and application times

	Number	Mean	Median (IQR)	p-value
Kron Technique (mmHg)	30	10.57±6.49	9.00 (5.75-15.25)	p=0.237**
Digital Manometer (mmHg)	30	10.48±6.67	8.46 (5.15-15.64)	
Kron Technique (seconds)	30	367.67±91.438	390.5 (286.75-401.25)	p<0.001*
Digital Manometer (seconds)	30	16.27±3.741	15 (14.75-16.25)	

*Sign test. **Wilcoxon signed-rank test

Table 3. Bland-Altman analysis of IAP measurements of patients

		95% Confidence Interval	
	Estimate	Lower	Upper
Bias (n=30)	0.091	-0.084	0.266
Lower Limit of Agreement	-0.825	-1.1272	-0.524
Upper Limit of Agreement	1.007	0.706	1.309

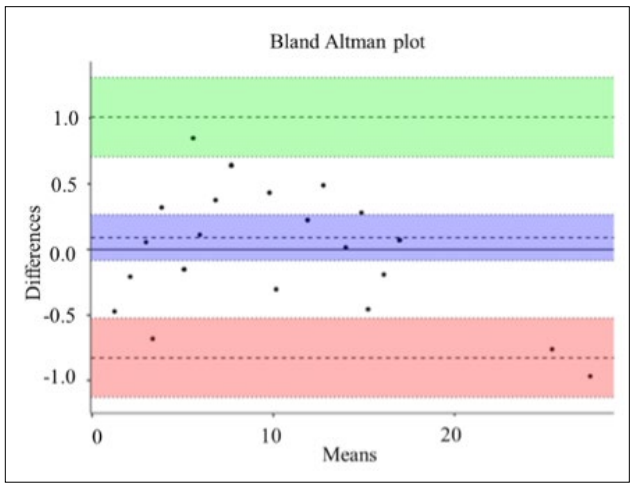

Figure 4. Bland-Altman analysis of IAP measurements of patients.

date. Indirect techniques, such as intragastric, intrauterine, intrarectal, intravesical, and using the inferior vena cava (IVC) route, as well as direct techniques like intra-abdominal catheters, have been extensively tested. Currently, the "Kron Technique" is regarded as the gold standard for intravesical IAP measurement. Other intravesical measurement techniques derive from the Kron Technique and are fundamentally based on the same principles.[1,3,7]

To the best of our knowledge, no studies have been conducted on the measurement of IAP using a digital manometer. Digital manometers are typically utilized for procedures such as thoracentesis and lumbar punctures, providing clinicians with rapid and practical pressure measurements. Results from these devices correlate well with classical methods.[8,9] In our study, we used a digital manometer for IAP measurement, demonstrating a strong correlation with the gold standard method, significantly shorter measurement times, and reduced consumable use.

The World Society of Abdominal Compartment Syndrome (WSACS) has recommended guidelines for future studies evaluating new IAP measurement methods. According to these guidelines, the number of patients should be ≥20, at least 50% of the measured IAP values should be ≥12 mmHg, and at least some measurements should exceed 20 mmHg (5%). Additionally, the bias value should be ≤1 mmHg, and the upper and lower limits of agreement should fall within ± 4 mmHg.[10]

When assessing the digital manometer measurements using Bland-Altman analysis according to these criteria, we find a bias value of 0.091 mmHg, with upper and lower limits of agreement at -0.825 and 1.007 mmHg, respectively.

Cheatham et al. reported that IAP measurement with classical methods took 3-5 minutes, which they managed to reduce to approximately 1 minute with a revised technique.[11] Similarly, Sekhri et al. compared digital manometer and classical water manometer methods for measuring cerebrospinal fluid (CSF) pressure during lumbar punctures, finding that classical methods averaged 45 seconds, whereas digital manometers took only 8-9 seconds.[9] In our study, the digital manometer significantly reduced the IAP measurement time by approximately 5-6 minutes compared to the gold standard method, offering a substantial advantage to emergency personnel.

In the Kron Technique, specific equipment is required, including pressure tubes, infusion sets, bedside monitors, and cables with transducer features for connecting the Foley catheter to the monitor.[5,11] The digital manometer used in our study connects directly to the urine sample port and displays results on its digital screen. This setup eliminates the need

for additional equipment beyond Foley catheters, syringes, and sterile fluid, thereby streamlining the IAP measurement process and offering convenience to emergency physicians.

In intensive care units, continuous arterial, central venous pressure, and IAP measurements are more common than in the emergency department. Using bedside monitors for pressure measurement requires additional training and adjustments. IAP measurement is not routine practice for emergency department staff. Since measuring IAP with a digital manometer does not require additional training, we consider it more useful for those working in the emergency department.

Although our study revealed a very strong correlation between both methods, it was conducted at a single center and included only patients diagnosed with ileus. Another limitation is that 43.3% (n=13) of the patients had IAP values above 12 mmHg, and 3.3% (n=1) had IAP values above 20 mmHg. This sample size may be insufficient to ensure that the comparison of both measurement methods yields consistent statistical results in cases of high intra-abdominal pressures. Consequently, we did not meet the WSACS criteria.

Intra-abdominal pressure measurement is also being tested with non-invasive methods. The goal is to find a more practical and accurate method for clinicians. For instance, a rat study conducted by Vincent et al. demonstrated the usability of the Graseby capsule for measuring intra-abdominal pressure by assessing abdominal wall movement, which could be a promising method for newborns and patients who cannot tolerate urinary bladder catheter insertion.[12] Additionally, Marcelo el al.'s trial of microwave reflectometry, although dependent on body mass index, is considered a method that can be further developed.[13]

CONCLUSION

When evaluating all these data collectively, we can conclude that the digital manometer and the Kron Technique yield similar IAP measurements, indicating a strong correlation between the two. This suggests that the digital manometer can serve as a viable alternative to the gold standard method, the Kron Technique. Additionally, we believe that the IAP measurement using a digital manometer is a technique that can be readily adopted by physicians and other healthcare professionals in emergency departments. It offers easy applicability, requires fewer pieces of equipment compared to the gold standard method, and provides rapid results with reliable measurement values. Since we did not perform a cost analysis, we cannot compare the two techniques in terms of cost.

Ethics Committee Approval: This study was approved by the Ankara City Hospital Ethics Committee (Date: 26.10.2022, Decision No: E2-22-2689).

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Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

İleus tanısı alan acil servis hastalarında karın içi basınç ölçümü için Kron tekniği ve dijital manometrinin karşılaştırılması

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AMAÇ: Karın içi basınç için birçok ölçüm tekniği denenmiş olmasına rağmen Kron tekniği şu anda altın standart yöntemdir. Ancak uzun uygulama süresi, daha fazla ekipmana ihtiyaç duyulması ve pratik olmaması nedeniyle diğer yöntem arayışları devam etmektedir. Sonuç olarak, acil serviste başarılı karın içi basınç ölçümü için uygun, daha hızlı ve daha erişilebilir bir yöntem araştırmaya çalıştık. Bu çalışmanın amacı ileus tanısı konulan hastalarda Kron Tekniği ve dijital manometre kullanılarak yapılan karın içi basınç ölçümlerini karşılaştırmaktır.

GEREÇ VE YÖNTEM: Çalışma Ekim 2022-Şubat 2023 tarihleri arasında üçüncü basamak bir acil servise başvuran ileus tanılı hastalar üzerinde yürütüldü. Tek merkezli, prospektif, tek kör, yöntem karşılaştırma çalışması olarak planlandı. İleuslu hastalarda karın içi basınç Kron Tekniği ve dijital manometre kullanılarak çalışmaya kör olan ayrı uygulayıcılar tarafından ölçüldü.

BULGULAR: Çalışmaya 30 hasta dahil edildi. Karın içi basınç ölçümlerinde iki yöntem arasında istatistiksel olarak anlamlı bir fark yoktu ($p<0.237$). İki yöntem arasında çok güçlü bir korelasyon bulundu (Spearman's Rho=0.998). Bland-Altman analizi, dijital manometre ölçümleri için 0.091 mmHg'lik bir sapma değeri gösterdi; üst ve alt uyum değerleri sırasıyla -0.825 ve 1.007 mmHg idi. Dijital manometre ile ölçüm süresi Kron tekniğine göre anlamlı derecede kısaydı (15 vs 390.5 saniye; $p<0.001$).

SONUÇ: Dijital manometre ile intraabdominal ölçüm tekniğinin, Kron tekniğine kıyasla kullanım kolaylığı, daha az ekipman gereksinimi, hızlı sonuç vermesi ve güvenilir ölçüm değerleri nedeniyle acil servislerde sağlık çalışanları tarafından kullanılabilecek bir yöntem olduğunu düşünüyoruz.

Anahtar sözcükler: Abdominal kavite; acil servis; manometre; ileus.

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