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A Novel Formula to Predict Intra-Abdominal Pressure Changes in Abdominoplasty

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ABSTRACT

Introduction: The desire to lose excess skin and fat in the abdomen is centuries old. Abdominoplasty presents a solution for this dilemma. Plication of the recti is becoming an integral part of the procedure leading to a more scaphoid abdomen. This reinforcement results in an increase in the intra-abdominal pressure that might lead to serious complications. Several methods have been used to measure & monitor the intra-abdominal pressure, yet the intra-vesical method remains the most common. The aim of this work is to design an equation for predilection of IAP at 24 hours postoperative based on the immediate post-plication IAP.

Patients and Methods: Patients undergoing abdominoplasty with muscle reinforcement were enrolled in this study. The intra-vesical route for measurement of intra-abdominal pressure was used. Measurements were done at induction, after plication, 12 hours post-operative and 24 hours post-operative.

Peak inspiratory pressure was recorded during the study at induction of anesthesia and after plication.

Results: Ninety patients fulfilled the inclusion & exclusion criteria. In the current study the mean intraabdominal pressure values at induction of anesthesia, post plication of the rectus abdominis, 12 hours post-operative, and 24 hours post-operative were 9.5cm H_2O, 12.45cm H_2O, 12.4cm H_2O and 9.87 respectively. The mean peak pressure at induction was 22.57 and the peak pressure post plication was 23.63. A special equation to predict IAP 24 hours post operative after measurement of the IAP post plication was formulated.

Conclusion: Intra-abdominal pressure measurement is important to avoid postoperative complications. The use of the cheaper two ways catheter yielded similar results to the complex three-way system with no recorded cases of urinary tract infection.

From the data collected in the current study an equation was reached that can aid surgeons in their clinical practice to predict the changes that might occur in the first 24 hours postoperative to attain the maximum safety and the best outcomes for the patient.

Key Words: *Divarication of recti – Plication – IAH – Abdominal compartment syndrome.*

Ethical Committee approval from the Department of Plastic Surgery, Cairo University.

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INTRODUCTION

Abdominoplasty is thought to be the most performed aesthetic procedure **[1]**. Despite the lack of accurate statistics, abdominoplasty represents a big chunk of the flow at any plastic surgery clinic. Its prevalence is multifactorial, either due to repeated pregnancies, weight fluctuation, ventral hernia, lack of proper exercise or due to the surge of bariatric procedures leading to increase in the demand for full abdominoplasty **[1]**.

The philosophy of procedure is to free the patient from the burden of the excess skin, elimination of the excess fat and to obtain a tight muscle corsage. The improvement of the silhouette comes at a price of a scar. All efforts should be made to make the scar as hidden and low as possible while maintaining the safety of the procedure **[2]**.

Reinforcement of the musculofascial system is becoming an integral part of abdominoplasty especially in women. It is believed, the tighter the reinforcement, the better the abdomen reaches its scaphoid shape. The tight internal corsage increases the intraabdominal pressure (IAP). The normal intra-abdominal pressure ranges from 3 and 15mmHg **[3]**.

Despite its popularity, abdominoplasty is not a risk-free intervention. Complications range from a minor wound dehiscence or infection to more serious problems like deep venous thrombosis (1.1% risk) & pulmonary embolism (0.8%). Myofascial reinforcement has been incriminated as it leads to intraabdominal hypertension (sustained elevation >12mmHg) diminishing venous return

& favoring venous stasis. Several publications studied the correlation between those 2 factors yet only limited studies measured the intraabdominal pressure and tried to reach clinical implications **[4]**.

Intraabdominal hypertension (IAH) and abdominal compartment syndrome (ACS) are not synonyms, yet they are always linked together. This is due to the magnitude of morbidity and mortality allied to them. Their impact affects the central nervous system, GIT, cardiovascular & pulmonary systems, liver and kidney **[5]**. Their effect on the abdominal wall itself is almost always forgotten. IAH vividly diminishes abdominal wall blood flow. Rectus sheath blood flow decreases up to 58% of baseline at an intraabdominal pressure (IAP) of only 10mmHg **[6]**. These findings may justify the impaired wound healing & higher rates of infection **[6]**.

The quest for the ideal methods to measure IAP is still on going. Pressure can be measured through any organ directly affected by the IAP. These readings can be done in a continuous or intermittent fashion. The well-established routes for assessment are through: The bladder, stomach, rectal, vaginal, inferior vena cava or through a direct peritoneal pressure **[7]**.

PATIENTS AND METHODS

A prospective study was conducted on patients presenting to the outpatient clinic of the Department of the Plastic & Reconstructive Surgery, Kasr Al-Ainy.

The selection method of abdominoplasty patients employed, has used specific inclusion and exclusion criteria to ensure that a relatively homogeneous sample is being treated, and that the treatment being offered is appropriate and reasonable for any given patient.

The inclusion criteria were: Diastasis of recti, scheduled to undergo elective abdominoplasty surgery without collateral procedures, age between 20-60 years, females: Not pregnant, not lactating and not planning to become pregnant for 2 years, being able to understand the study procedures and comply with those procedures and agree to participate in the study program and lastly no previous abdominal surgeries.

While the exclusion criteria were: Underlying co-morbidities (e.g.: diabetes, hypertension, renal disease, COP, asthmatic), previous history of thromboembolic event or have a known bleeding disorder or taking agents affecting coagulation, BMI >35 (as it is known to affect IAP), ventral hernias and smokers.

Patients fitting those criteria underwent thorough history taking as well as local and general examination. Presence of the divercation of recti was a key element in this study without any ventral hernias. Routine pre-operative labs and subcutaneous ultrasound (to exclude any hernia not clinically detected) were done.

Sample size was calculated using STATA with alpha 0.05 and power 80%. With this alpha and power, we needed 90 participants to detect differences in intraabdominal pressure. The data wasn't normally distributed so nonparametric Spearman test was used.

On the day of surgery, pre-operative antibiotic was administered. All patients were operated upon under general anesthesia. Peak inspiratory pressure is defined as the highest level of pressure applied to the lungs during inspiration. Two measurements were recorded during the study at induction of anesthesia and after plication. Patients were positioned supine with pillows under the knees to relieve stress on the sciatic nerve if the table is to be flexed. The abdomen up to the mid-chest and down to the groins was prepped and draped to maintain sterility during post plication measurements. Insertion of a Foley's urinary catheter under complete sterile conditions. Plication of the anterior rectus sheath from the xiphoid to the symphysis was accomplished using non-absorbable suture material. Fig. (1) It was done both supra-umbilical and infra-umbilical. Quilting sutures weren’t used in any patient.

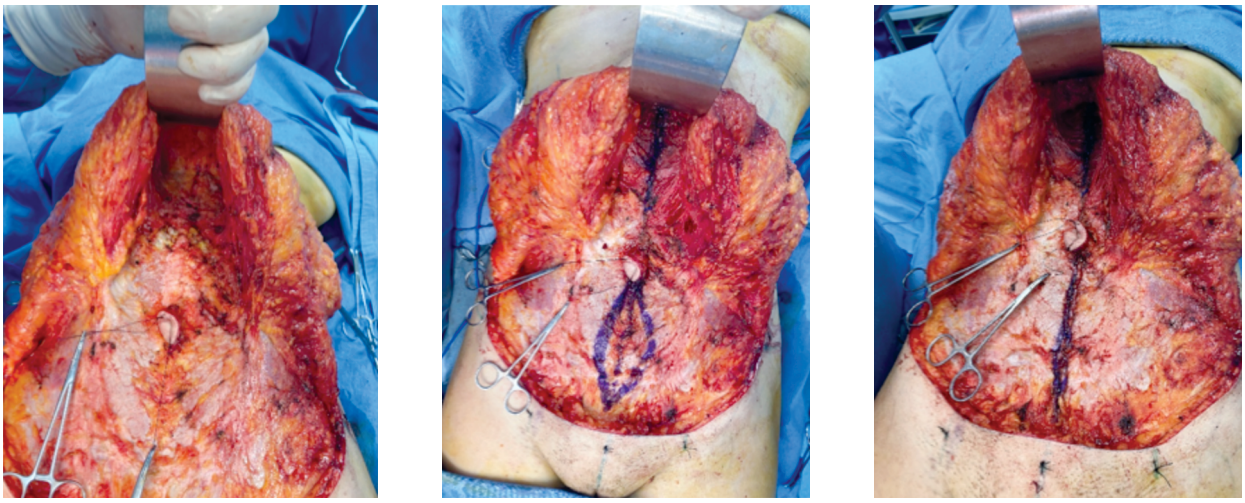
Bladder measurement was the preferred method done in this study for IAP. The tools needed were: A Foley's catheter, peripheral line, 500ml bottle of saline, 2 wide nozzle 50cc syringes filled with saline, a ruler and the sterilization pack. Fig. (2).

The technique for intra-abdominal measurement was as follow: Disconnecting the patient's Foley's catheter from its collecting bag and instilling 100ml of saline with the two 50cm Ryle syringes using a sterile field (a challenge was faced when less than 50ml of saline were instilled as air bubbles appeared in the intravenous line leading to inaccuracy of measurements).

The intravenous line at the side of drip chamber is attached to the 500ml saline bottle, then line is filled with saline. The roller flow control clamp is closed. The Luer lock collar is inserted in the

rubber end of the Foley's catheter then the roller flow control clamp is opened, and the column of water is observed till it levels.

It is to be noted that the zero point is at the level of symphysis pubis because the zero-reference level has an important impact on intra-abdominal pressure measurement and can potentially lead to over or underestimation. While the column of water is measured and recorded using the centimeter ruler. Fig. (3).



(A) (B) (C)

Fig. (1): Serial pictures of the same patient illustrating the state of abdomen before plication (A) after plication of the supra-umbilical portion (B) & the final plication result (C).

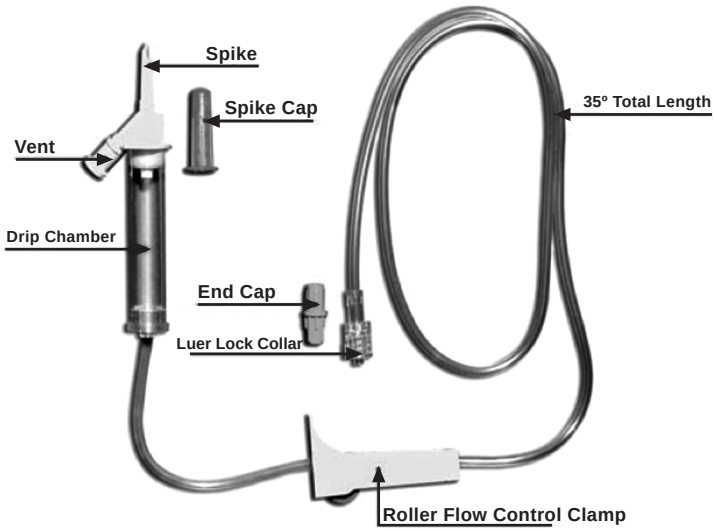


Fig. (2): Peripheral line highlighting the terms of each component.

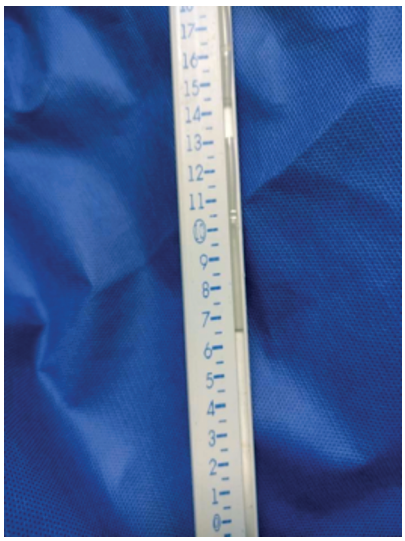


Fig. (3): Measurement of IAP. The fluid level at 6.5cm H_2O.

After IAP determination, the collecting bag is re-attached, the bladder is allowed to drain, and the volume of saline utilized subtracted from the patient's urinary output for that hour.

Four measurements were taken during the study which were taken after induction of anesthesia, post plication, 12 hours post-operative and 24 hours post-operative. The post plication measurement was delayed till end of surgery so as not to disturb sterility and decrease chances of sepsis.

In addition to the regular post-operative instructions of abdominoplasty, patients were ambulated as early as possible post-operative & were instructed to rest in a relaxed position with a flexion of approximately 30° at the hip joint. This position ought to be retained for 2 weeks post-operatively, to assure a tension free healing of the scar. A suction drain was inserted in all cases.

RESULTS

The study was conducted on 90 patients. All patients were females with a mean age of 35.87. More than half of the study population (53%) were between the ages of 30 to 39. The cases in this study all had a BMI of <35 with a mean 31.27. (Minimum of 27 and maximum of 35).

The mean IAP measurement at induction was 9.5 with a minimum of 6cm H_2O and a maximum of 15cm H_2O. 47% of the patients had an initial IAP pressure measurement at induction of anesthesia between 6-8cm H_2O.

The mean IAP measurement post plication was 12.45 with a minimum of 9cm H_2O and maximum of 18cm H_2O. 40% of the patients' IAP measurement was between 9cm H_2O and 11cm H_2O.

While the mean IAP measurement at 12 hours post operative was 12.4 with a minimum of 8cm H_2O and a maximum of 21cm H_2O. 44% of the patients' IAP measurements at 12 hours post-operative were between 9cm H_2O and 11cm H_2O.

Later on, at 24 hours post-operative the mean IAP was 9.87 with a minimum of 7cm H_2O and a maximum of 16cm H_2O. 40% of the patients' IAP measurements were between 6-8cmH_2O.

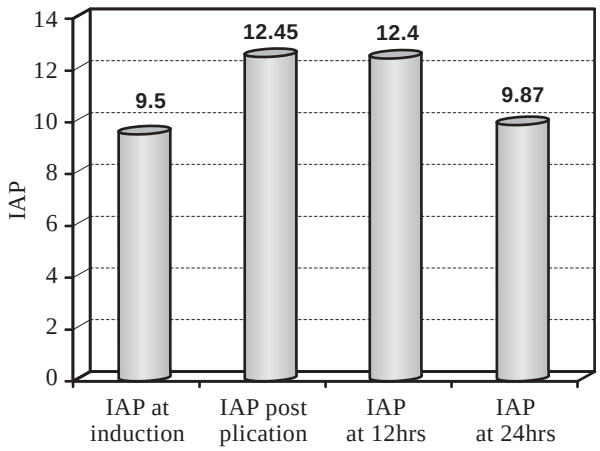


Fig. (4): The mean of Intra-abdominal pressure at induction, post plication, 12 hours, and 24 hours post-operatively.

The intra-abdominal pressure increased by an average of 34.75% between that at induction of anesthesia and post plication. Later on, IAP decreases by an average of 0.08% post plication and at 12 hours post-operatively. Another significant decrease occurs (19,45%) between IAP at 12 hours and 24 hours postoperatively. IAP decreased by an average of 21.11% between post plication and 24 hours post-operative. Table (1).

Table (1): IAP Percentage of change among the 4 measurements.

	Mean	Standard Deviation	Median	Min-imum	Max-imum
- IAP percent change post plication	34.75	20.59	25.00	7.14	77.78
- IAP percent change at 12 hours	-.08-	15.51	.00	-38.46-	33.33
- IAP percent change at 24 hours	-19.45-	14.86	-20.71-	-43.75-	25.00
- IAP percent change at 24 hours Compared to post plication	-21.11-	10.19	-22.65-	-41.67-	.00

The above correlations between the four IAP measurements (between the quantitative variables) were done using Spearman correlation and results where statistically significant with a *p*-value <0.001. Hence Linear regression analysis was done using IAP percent change at 24 hours compared to post plication as dependent variable and IAP percent change post plication as independent predictor. Table (2).

This resulted in the following equation to predict IAP 24 hours post operative after measurement of the IAP post plication.

Equation:

IAP at 24 hours = 2.039 + (0.956 x IAP post plication)

Table (2): Linear regression analysis to detect IAP percent change at 24 hours compared to post plication (dependent variable) using IAP percent change post plication as independent predictor.

Model	Unstandardized Coefficients		Standardized Coefficients	*t*	*p*-value
	B	Std. Error	Beta		
- (Constant)	-2.039-	1.262		-1.615-	.117
- IAP post plication	.956	.100	.876	9.592	<0.001

The peak inspiratory pressure was measured at induction of anesthesia and post plication. The mean peak pressure at induction was 22.57 and the peak pressure post plication was 23.63. The peak inspiratory pressure (PIP) increased 4.77% post plication. Table (3).

Table (3): Percentage change of PIP at induction and post plication.

	Mean	Standard Deviation	Median	Minimum	Maximum
- Peak percent change post plication	4.77	9.04	4.45	-7.69-	38.10

DISCUSSION

Abdominoplasty has a positive impact on a patient's life. A lot of patients call it a life changing procedure as it improves how they perceive themselves. This change increases their self-confidence and permits them even to lead a healthier lifestyle and exercise better **[8]**.

The procedure is over a century old nevertheless; like all branches of plastic surgery, it has been under continuous changes and innovations. Yet all these changes and improvements share common aims: Relieving the patient of the burden of excess fat and skin, amendment of the musculo-aponeurotic looseness (diastasis recti) and reaching the well desired shape **[9]**.

Though it is one of the most performed procedures, the incidence of complications in abdominoplasty can be up to 4% versus 1.4% in other aesthetic surgery procedures. Of these, hematomas accounted for 31.5%, 27.2% were infections and suspected or confirmed DVT represented 20.2% **[10]**.

When the phrase 'compartment syndrome' is mentioned the first thing that comes to mind is extremities and the abdomen is often overlooked. The abdomen appears to be a supple area that can withstand any increase in pressure, yet it's still a compartment. The boundaries of which are formed from fixed boundaries (spine, pelvis, and costal margin). While the more flexible and pliable boundaries include the diaphragm and the abdominal wall. That explains why reinforcement of the abdominal wall can have a direct impact on intra-abdominal pressure **[11]**.

Increased pressure can lead to affection of the structures inside the abdominal compartment. The adverse effect usual occurs with a persistent increase of IAP to 12mm Hg or greater. The cascade of events is not limited to the local area of the abdomen (gut and major vessels) but extends remotely to reach all systems in the body **[5]**. IAP of over 20 can lead multiorgan system failure **[6]**.

During plication of the recti, plastic surgeons are faced with 2 conflicting decisions. One is that plication yields excellent results giving the patient the scaphoid abdomen they desire. Two, the haunting idea of over plication and their adverse effects usual overshadows plication decision.

Assessment of IAP clinically is not reliable. This study tried to reach an objective method for assessment of the strength of plication and reaching numerical values that might help the surgeon sleep better assured with his or her decision.

Like how you cannot diagnose fever without measuring the temperature, we cannot claim to understand IAP without measuring it. Multiple methods and techniques have been used for IAP measurement still the intra-vesical route measurement proved its superiority. The technique is not standardized as it has considerable variability. Those include the malposition of the pressure measuring device and the distortion produced by each pressure transducer due to their own dynamic response **[12]**.

This study was conducted only on female patients due to the variability of muscle tone between males and females. In a lot of cases male patients are not candidates for plication. While on the other hand, with the repeated pregnancies and lack of exercise most of the female patients needed some sort of plication.

Extremes of age were excluded. Younger patients usually have good musculatures while older are more prone to complications. The mean age was 35.87 years (min 27 max 57). This is in harmony with multiple studies with age range 26 to 60 years (mean 38.6) **[9,13,14]**.

The body mass index (BMI) of all patients in the study at hand, varied between 27 and 35 with an average of 31 as the exclusion criteria included BMI over 35. Higher BMI is implicated in increasing the complication rate as well as inaccuracies in the IAP pressure reading (higher with obesity). While Neto et al., **[14]** included patients with BMI between 24 and 29 and in Talisman et al.'s **[9]** study ranged 25-47, with also an average of 31. Al Basti et al., **[13]** conducted a prospective study on morbidly obese women with a mean body mass index 36.

All the patients underwent the procedure under general anesthesia. General anesthesia allowed the measurement of the IAP with the patient completely relaxed and recording the peak airway pressure before and after plication of the recti. Talisman et al., **[9]** & Basti et al., **[13]** also performed all their procedures under general anesthesia while Neto et al., **[14]** patients' received epidural anesthesia.

Monitoring of IAP can be performed by several different ways. Intra-vesical measurement was done in all mentioned studies (including the current study) due to its simplicity and accessibility in a catheterized patient.

Intra-vesical measurement can be done with different techniques. In the current study after initiation of anesthesia, with the patient in the supine position, a two-way Foley bladder catheter was placed through the urethra while the other studies used a three-way Foley's catheter **[9,13,14]**.

The other studies were seeking a closed system technique to avoid urinary tract infections thus they used a three-way catheter. A three- way Foley's catheter has an extra irrigation port to the standard balloon inflation port and urinary drainage port, allowing injection of the required amount of saline without separating the urinary collecting bag from the urinary drainage port, hence having a closed system, decreasing the occurrence of infection.

However, in this study despite the use of a two-way Foley's catheter as an open system, because it was more feasible and more economical with the available resources, no cases of urinary tract infections were reported. Also it is important to note that the mean IAP values (mentioned below) and results were similar in all three studies **[9,13,14]**, hence the use of a 2 way Foley's catheter didn't have a drastically different outcome on this study.

In this study, as well as in the studies of Talisman et al., **[9]** 50-100ml of saline were injected in the bladder through the catheter's port after emptying it, which is in harmony with Neto et al.'s **[14]** study. As opposed to Al Basti et al., **[13]** who injected 350ml of normal saline, just below the volume required to initiate the bladder muscle contraction. The injection of less than 100cc of normal saline lead to air bubbles in the system.

In this study, as well as in the studies of Talisman et al., **[9]** and Neto et al., **[14]** all measurements were obtained when the zero standard level was at the level of the patient's symphysis pubis to avoid under or over estimation of intra-abdominal pressure. However, in the study of Al Basti et al., **[13]** the zero standard level was at the level of the patient's heart.

During the conduction of the study at hand, it was decided to take the intra-abdominal pressure measurements at induction of anesthesia, post plication of the rectus abdominis, 12 hours post-operative, and 24 hours post-operative. In the studies of Talisman et al., **[9]** and Neto et al., **[14]**, a pre-operative measurement of the intra-abdominal pressure was measured, then an immediate post-operative and 24 hours post-operative measurements were taken. In Al-Basti et al.'s **[13]** study measurements were obtained immediately after induction of anesthesia, after completion of muscle plication and after skin closure.

In the current study the mean intraabdominal pressure values at induction of anesthesia, post plication of the rectus abdominis, 12 hours post-operative, and 24 hours post-operative were 9.5cmH_2O, 12.45cmH_2O,12.4cmH_2O and 9.87 respectively, which were similar to those conducted by Talisman et al., **[9]** with mean values 8cmH_2O pre-operatively, 15cmH_2O post-operatively day 0, 12cmH_2O post-operatively day 1, and conducted by Neto et al., **[14]** with mean values 4.66cmH_2O pre-operatively, 13.41cmH_2O post-operative day 0, and 8.41cmH_2O post-operative day.

The recording of peak inspiratory pressure was chosen in this study to assess the impact of surgery on intrathoracic pressure and was recorded immediately after induction of anesthesia and at the end of surgery. In both studies done by Talisman et al., **[9]** and Al-Basti et al., **[13]** the same parameter was used to assess the intrathoracic pressure, but Al-Basti et al., **[13]** added assessment of pulmonary functions two months post-operatively, with measurement of flow volume loop, forced vital capacity, forced expiratory volume in 1 second, peak expiratory flow, forced expiratory flow, and peak inspiratory force to exclude the effect of postoperative pain and to allow for muscular adaptation, in addition to the different purpose of their study which is evaluating any potential adverse effect on pulmonary function.

After plication, plastic surgeons face the dilemma of “is this plication too tight?” 'Should plication be undone'. From all the data collected in the current study, an equation to predict the IAP value at 24 hours was formulated, after calculation of IAP value post-plication. Though the equation appears to be complicated it is worth it. The equation aids surgeons intra-operatively after doing plication, to predict the outcome of surgery and know the expected rise of IAP after 24 hours.

This study faced multiple limitations including the fluctuation that occurred in IAP readings with changes in patient's position. The presence of air bubbles in the line might also affect the measurement. It is also recommended to correlate between the IAP and complications of abdominoplasty itself (as regards wound healing).

Conclusion:

Abdominoplasty is one of the most commonly performed procedures in plastic surgery yet, like any surgical procedure it is not free of complications. One of those is intra-abdominal hypertension

which cannot be properly diagnosed and managed without the measurement of the intra-abdominal pressure.

The use of the cheaper two ways catheter yielded similar results to the complex three-way system with no recorded cases of urinary tract infection.

More importantly, from the data collected in the current study an equation was reached that can aid surgeons in their clinical practice to predict the changes that might occur in the first 24 hours post-operative in order to attain the maximum safety and the best outcomes for the patient.

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