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Diagnostic Accuracy of Intra-Abdominal Pressure Measurement Method via Bladder in Predicting Renal Dysfunction after Kidney Transplantation

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Abstract

Background: The patients undergoing kidney transplantation are exposed to Intra-Abdominal Pressure (IAP) elevation following a surgery.

Aim: The present study aimed to evaluate the diagnostic accuracy of the IAP measurement method via bladder in the prediction of renal dysfunction after kidney transplantation.

Method: This longitudinal study was conducted on 135 kidney transplant patients in two hospitals in Iran/Afghanistan from February 2019 to the end of October 2019. The patients' IAP was measured by nurses every 6 h up to 24 h after the surgery. The indices of renal dysfunction were utilized, including creatinine increase and urine reduction. Doppler ultrasound was used as a golden standard diagnostic test. Data were analyzed in STATA 14.

Results: Out of 135 patients, an increase in IAP>10 mmHg was observed in 9.5% of cases. Urinary loss and creatinine decrease more than 25% of baseline indicated a significant correlation with IAP mean difference (P=0.001) (4-1). Therefore, IAP could predict renal dysfunction based on the reduction of urinary volume and a decrease in creatinine of more than 25% of baseline. Finally, a comparison between the diagnostic power of the IAP measurement method and Doppler ultrasound indicated 90% of sensitivity and 94% of negative predictive value in predicting renal dysfunction.

Implications for Practice: As evidenced by the obtained results, the IAP measurement via bladder catheter might be a primary test to predict renal dysfunction before Doppler ultrasound; nonetheless, further research is required.

Keywords: Intra-abdominal pressure (IAP), Kidney transplantation, Renal dysfunction

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Introduction

Kidney transplantation is the best treatment method for patients with kidney failure, providing them with the highest survival benefits among other alternative therapies. It also leads to the prevention of many complications of chronic kidney failure, enhancement of life quality, and prolongation of life (1). Despite the fact that kidney transplantation is an appropriate selective treatment in patients with renal failure, the emergence of internal and subsequent surgical complications could exacerbate high-risk conditions, such as transplant rejection, delayed graft function, kidney deficiency, and even patient death (2, 3).

Kidney deficiency is almost one of the complications of transplantation occurring as a result of tubular necrosis or poor connective tissue function. This complication might occur immediately after the surgery or some months or years after, leading to kidney failure, transplantation rejection, and even death (4). Urine volume is one of the current indices for the evaluation of kidney deficiency range after transplantation (2). Therefore, the insertion of a urinary catheter is one of the most requirements after the surgery to measure the exact volume of urine (5). Thereafter, the first 24 hours after the surgery is the golden time for the assessment of transplanted kidney function by special nurses (6, 7). The nurse who takes care of the patient undergoing transplantation plays a substantial role in the diagnosis of acute transplant complications that often occur during the first 24 hours after transplantation. The nurse is able to diagnose complications, such as renal dysfunction, appearing in the form of decreased urinary output and increased serum creatinine with obtained knowledge and urgent intervention (6, 7).

An increase in Intra-Abdominal Pressure (IAP) is one of the complications of abdominal surgeries, such as kidney transplantation. Intra-abdominal hypertension (IAH) reduces blood supply to the transplanted kidney and eventually leads to its ischemia. This phenomenon is defined as kidney transplantation compartment syndrome which might remain undetectable. This syndrome is further likely to be confused with many transplantation complications, such as vascular thrombosis and other surgical complications (8, 9). According to the Abdominal Compartment Syndrome Association, IAP measurement is recommended for all the patients who are hospitalized in intensive care units with such clinical conditions as abdominal surgeries, ascites, and abdominal trauma that may expose patients to Abdominal Compartment Syndrome (ACS)(8). Intrabladder pressure monitoring has been introduced by the Abdominal Compartment Syndrome Association in 2006 as the simplest, the most cost-effective, and the most reliable method for the measurement of IAP (8, 9).

Based on the literature review, some studies have assessed the incidence of acute compartment syndrome and IAP in patients who experienced abdominal trauma or underwent abdominal surgeries, such as kidney transplantation, in surgical wards and critical care units (1, 10-12). In these studies, the ACS was estimated at 1%-2 % in patients with abdominal trauma or surgery (9, 13, 14). Although in all of these investigations, the patients had IAP measurements via the bladder and the suspicious patients were followed up by sonography, none of them evaluated the diagnostic accuracy of the IAP measurement method via the bladder, in comparison with other diagnostic methods, such as Doppler Abdominal ultrasound, urine volume, and blood creatinine results.

Given that nurses are permanent caregivers of patients (15, 16), it would be ideal to use a simpler and more economical diagnostic method, which can be performed by nurses and predict renal failure in kidney transplant patients. In light of the aforementioned issues, the present study aimed to evaluate the diagnostic accuracy of the IAP measurement method via bladder catheter in predicting the probability of renal dysfunction after transplantation.

Methods

This single-group longitudinal study was conducted on patients admitted to two kidney transplantation centers in Iran and Afghanistan from February 2019 to the end of October 2019. The patients who received kidney transplantation entered the study in coordination with the related physician based on inclusion criteria: the age range of 13-65 years and the absence of urinary tract or neurogenic bladder disorders. On the other hand, the exclusion criteria were as follows: unwillingness to participate in the study, absence of bladder transplantation, intolerance of testing, the incidence of respiratory distress, hemodynamic changes, non-authorization by the physician, and suprapubic catheter placement. The IAP measurement via bladder was performed every 6 h after transplantation for 24 h. Following that, it was performed every 48 and 72 h after transplantation if IAP$\geq$ 12.

The sample size was calculated at 135 cases using PASS statistical software and a relative article (17).

The aim was to compare the mean IAP of patients who experienced kidney failure and the patients without kidney failure. Therefore, considering 90% power, alpha 0.05, four times IAP measurement, the effect size of 0.85, and the correlation of frequencies of 0.6, the sample size was estimated at 135.
Before the commencement of the study, the following information was recorded: 24-hour urine volume, type of dialysis (hemodialysis or peritoneal), and history of previous transplantation (Table 1). Each patient's postoperative information was also recorded and examined, including vital signs (pulse, blood pressure), the rate of intake and output within the first 24 hours after transplantation, IAP measurement (through Crohn's Method) every 6 h up to 24 h after transplantation, laboratory parameters (e.g., hemoglobin, hematocrit, urea, and creatinine) during the first 24 hours after transplantation, level of hemoglobin and creatinine a week after surgery, the need for dialysis and Thymoglobulin, and the results of renal artery Doppler ultrasound, as well as transplanted kidney sonography within the first 24 hours after transplantation.
In the present study, IAP measurement via the bladder catheter was utilized considering the constraints in two countries with simple urinary catheters which are not equipped with culture aspiration port from each patient's urinary tube ─as a route of water elevation along the scale of a centimeter of water. Here, the capillary effect (i.e., the tendency of liquid to rise in low-diameter tubes) was used. The present study was initiated by placing the patient in a supine position so that the abdominal muscles were in a relaxed state. It was proceeded by entering 50 cc normal saline slowly into the bladder through the path connected to the urine bag. Thereafter, the path was clamped, and the urinary bag tube was emptied. Following that, the scale zero point was placed at the joining point of the iliac spine and armpit midline at the same level or Pubic symphysis of the patient. The tube of the urinary bag was also fixed from the junction to the catheter at zero point, and the rest of the urinary tube was held at the zero level of the scale. After 30-50 sec, the patient was asked to hold his breath, and the clamp was then opened for urine to move along the path of the urinary bag tube and rise through the scale level. The number indicated IAP at the point where urine stopped and fluctuated with the patient's breath (Figure2).

Table 1. Frequency distribution of demographic and disease information of patients undergoing kidney transplantation

Variable		Frequency(Percentage) n=135
Gender	Male	92 (68.1%)
	Female	43 (31.9%)
Dialysis	Blood	123 (91%)
	Peritoneal	12 (9%)
Kidney transplantation Iran	Live	12 (9.9%)
	Cadaver	81(60%)
Kidney transplantation Afghanistan	Live	42 (31.1%)
	Cadaver	0 (0%)
High Blood pressure	Yes	30 (22.2%)
	No	105 (77.8%)
Diabetes	Yes	4 (3%)
	No	131(97%)
Mental Illness	Yes	4 (3%)
	No	131(97%)
Substance abuse	Yes	3 (2.2%)
	No	132 (97.8%)
Cardiovascular diseases	Yes	4 (3%)
	No	131(97%)
Taking medication for illness	Yes	23(18%)
	No	112 (83%)
Observed urine before the surgery	Yes	9 (6.7%)
	No	83 (61.5%)

The most important point in IAP measurement is the zero point of the scale or transducer that should be placed in the mid-axillary and iliac lines parallel to the pubic symphysis. An appropriate volume of the bladder, as well as a minimum time of 30 sec, is necessary to relax the bladder muscles. Entering an excessive volume of fluid or allowing the bladder to relax too much results in a false high IAP value. Body position can contribute to an accurate IAP value so that bed height above 10-20 degrees can lead to a false high IAP value (18).

According to the Abdominal Compartment Syndrome Association, there are three grades for IAP: grade (1): IAP range of12-15 mmHg, grade (2): IAP range of 16-20 mmHg, and grade (3): IAP range of 21-25 mmHg(8). The indices used to predict renal dysfunction included the urinary output less than 100 cc/h, lack of creatinine depletion of less than 25% of baseline, Delayed Graft Function (dialysis requirement in the first week of transplantation), and Doppler sonographic changes (increase in vascular resistance). After the collection and encoding of data, they were analyzed in STATA software (version 14).

Regarding statistical tests, the Mann-Whitney test was initially performed to assess the association of IAP variables or their conversions with dichotomous variables, indicating renal dysfunction (i.e., decrease of urine volume lower than 100 cc/h, creatinine depletion index less than 25% of preoperative baseline creatinine, and delayed function of the transplanted kidney). Thereafter, the predictive power of IAP variables for renal dysfunction was evaluated using the Receiver Operating Characteristic (ROC) curve. The sensitivity and specificity, as well as positive and negative predictive values, were calculated by considering the area under the curve for each of their values (cut-off point). Subsequently, a combination of tests with maximum sensitivity, specificity, and predictive values was administered in series (sequential) and parallel forms employing the multiple testing approach. The basis for comparing the cut-off points was the predictive or diagnostic power of Youden's (Youden's= (Sensitivity+ specificity) -1) and d2 (d2= (1-sensitivity) 2+ (1- specificity) 2) indices. Finally, a final cut-off point with the highest Youden's index and the lowest d2 index was recorded. Finally, the sensitivity and specificity identified in the Youden's and d2 indices were determined in IAP differences of 1-4 and 1-3. Multiple sequential and parallel testing methods were used, and sensitivity and specificity were determined by combining these tests in parallel-sequential multiple tests (13, 19).

Given the low incidence of renal dysfunction among the patients in the present study, sensitivity, which indicated the ability of a test to detect cases of the disease, was considered to be more important in this study. On the other hand, the low incidence of renal dysfunction among the patients under study caused the negative predictive value of the test to be important since this index showed the ratio of healthy cases to all the cases with negative test reports. Therefore, the current study put greater emphasis on determining the negative predictive value of the test. In this regard, a combination of parallel statistical tests was used with the highest sensitivity and negative predictive value.

Results

Women and men comprised 31.9% and 68.1% of the patients under study, respectively (Table1). The results demonstrated that hypertension (22.2%) was the most prevalent chronic disease (Table1). Among the transplant patients during the research period, three patients were excluded due to neurogenic bladder (n=2), as well as urethral stricture and suprapubic catheter insertion (n=1). Finally, 135 patients were included in the study, and their data were analyzed (Figure1). Out of 135 patients, only 4 patients experienced IAP increase higher than 10, and 43 patients (31.6%) had at least one IAP higher than 8 in four IAP measurements in a day. Renal dysfunction had a low prevalence with a 15% of incidence.

In the present study, for the prediction of renal dysfunction, the means of IAP were compared using the Mann-Whitney test based on creatinine depletion index less than 25% of preoperative baseline creatinine as a dichotomous variable during a week after surgery. The test results illustrated that patients with less than 25% of creatinine depletion from the baseline in the first week after surgery had a significantly higher IAP mean difference than normal patients. There was also a significant correlation between IAP (1-4) difference and creatinine depletion index (P= 0.001) (z= -3.24) (Table 2).

A parallel test was used to determine the sensitivity and negative predictive value using multiple testing approaches and considering the low incidence of renal dysfunction. Accordingly, higher IAP

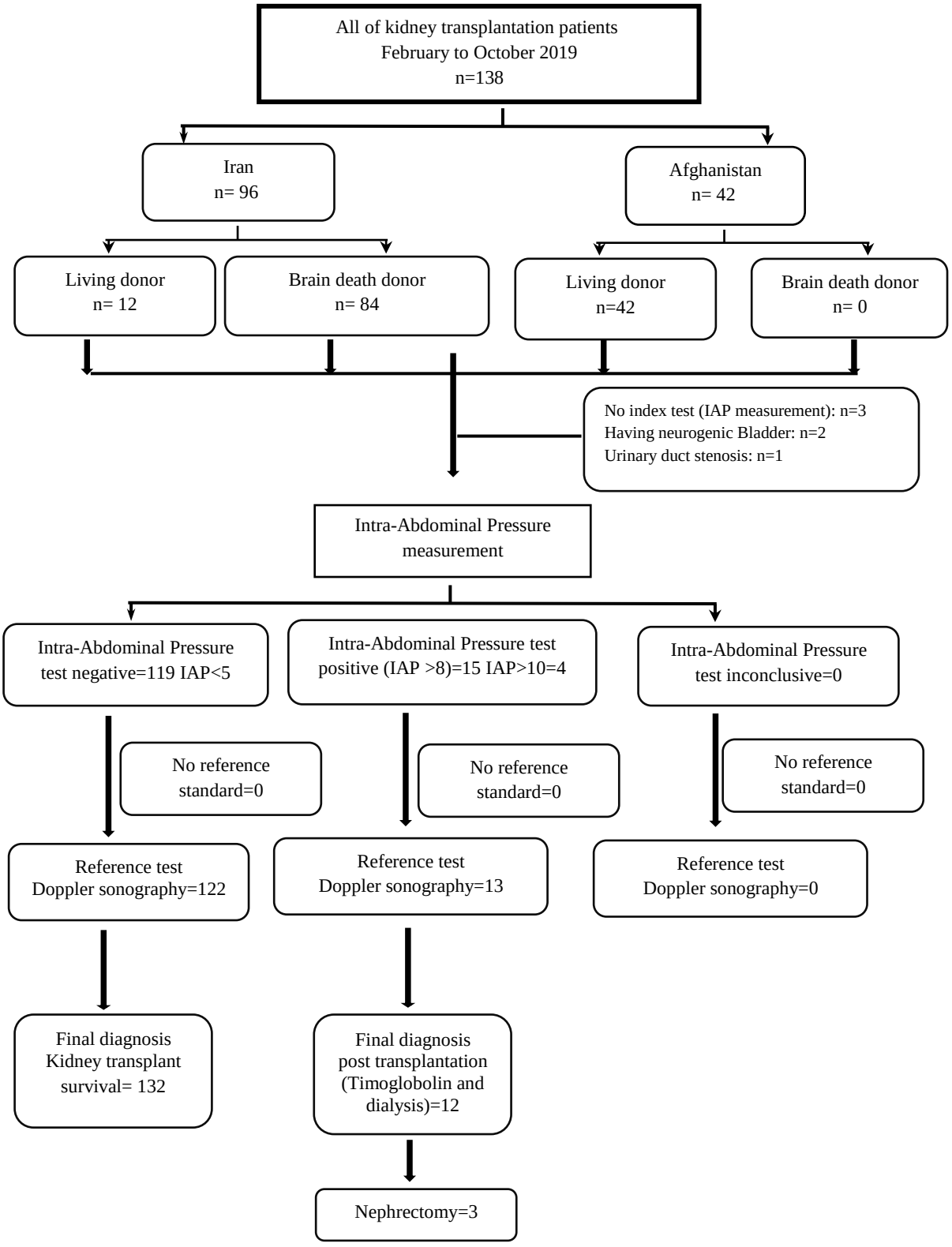

Figure 1. STARD flow diagram of the study

correlated with lack of creatinine depletion index more than 25% of baseline could predict the renal dysfunction with 98% of sensitivity, 98% of negative predictive value, 24% specificity, and positive predictive value of 18%.

Furthermore, IAP means were examined and then compared using the Mann-Whitney test based on a urinary volume index of less than 100 cc/h as a dichotomous variable within the first 24 h after

Table 2. Comparison of the mean and standard deviation of intra-abdominal pressure in patients undergoing kidney transplantation with two-state indices of renal adequacy assessment

Variable	Number-Percentage	Mean (SD) IAP 1	median	IQR	Mean(SD) IAP 4	median	IQR	Mann-Whitney test P-value
Urine volume less than 100 cc/h	7 5.2%	5.87(3.32)	6	3	6.71(5.02)	5	4	Z =-3.27 P-value= 0.001
Urine volume greater than 100 cc/h	129 94.8%	3.73(3.35)	2.5	4.5	4.75(5.175)	3.5	8	
Creatinine Reduction less than 25% of baseline in the first week after surgery	20 15.1%	5.94(3.49)	6	4	4.19(2.83)	4	4	Z =-3.24 P-value= 0.001
Creatinine reduction greater than 25% of baseline in the first week after surgery	113 84.9%	4.52(2.32)	5	3.75	5.7(2.7)	5	2.5	
Need for dialysis after transplantation	12 9%	3.70(3.15)	2.75	3	5.41(3.42)	5	5	Z=- 2.97 P-value = 0.002
No need for dialysis after transplantation	123 91%	5.92(3.33)	6	3	4.30(2.7)	5	4	
Patients with high vascular resistance in Doppler ultrasound	13 9.6%	4.96(3.46)	5	3.5	6.23(4.54)	5	3	Z =-2.19 P-value = 0.01
Patients with normal vascular resistance in Doppler ultrasound	122 90.4%	5.8(3.35)	6	3	4.28(2.73)	5	4	

transplantation. The obtained results showed a significant correlation between the IAP (1-4) difference and urinary reduction in the prediction of renal insufficiency (P=0.001) (z= -3.27). It suggested that patients with lower urine experienced higher IAP mean, as compared to other patients (Table 2).As a result, higher IAP correlated with urinary loss index could predict renal dysfunction with a sensitivity of 91%, a negative predictive value of 97%, specificity of 73%, and a positive predictive value of 15% (Figure2).

In line with renal dysfunction evaluation, delayed graft function rate was investigated as an indicator of renal insufficiency. According to sources, delayed graft function is explained by the need for dialysis due to renal insufficiency in the first week after transplantation. In the current study, means of IAP were compared using the Mann-Whitney Test and based on dialysis

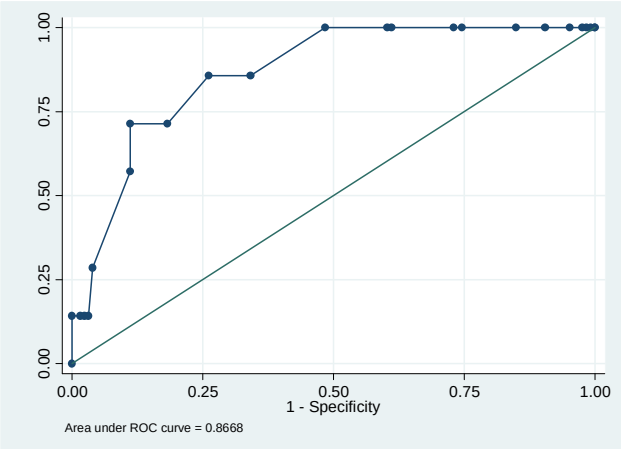

Figure 2. Receiver Operating Characteristic Curve 2. Relationship between the intra-abdominal pressure mean difference (1-4) and decreased urination less than 100 cc

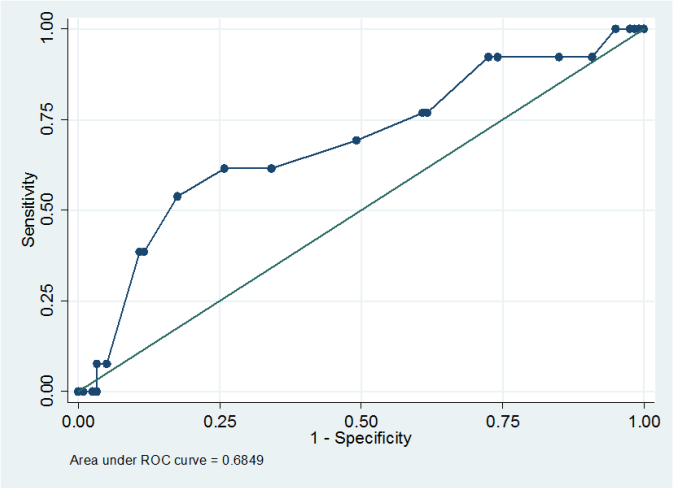

Figure 3. Receiver Operating Characteristic Curve 3- Relationship of intra-abdominal pressure difference 1-4 with intravascular resistance according to Doppler Sonography

requirement index as a dichotomous variable within the first week after transplantation. The results revealed that those patients in need of postoperative dialysis had a higher mean of IAP. The dialysis requirement index was further significantly correlated with IAP (1-4) difference (P= 0.002). (z= -2.97) (Table 2). In this regard, higher IAP correlated with dialysis index was able to predict renal dysfunction with 96% of sensitivity, the negative predictive value of 98%, specificity of 56%, and positive predictive value of 17%.

Moreover, the prediction of renal dysfunction and means of IAP were evaluated on the basis of nephrectomy incidence index as a dichotomous variable, and the means were then compared by the Mann-Whitney Test. The results pointed out that the patients who had undergone postoperative nephrectomy had a significantly higher first mean of IAP, as compared to those with no nephrectomy-related problem (P=0.05; z=1.97) (Table 2). The parallel test was utilized to determine the sensitivity and negative predictive value using the multiple testing approach. Therefore, higher IAP based on nephrectomy index could predict renal dysfunction with 94% of sensitivity, 99% of negative predictive value, specificity of 51%, and positive predictive value of 7%.

Furthermore, after kidney transplantation, a comparison was made between Doppler ultrasound and IAP as a dichotomous variable. The first group contained those patients who experienced higher venous resistance in Doppler ultrasound of the transplanted kidney, while the second group had normal Doppler ultrasound of transplanted kidney. The two groups were compared using the Mann-Whitney test, and the results indicated that the patients with higher venous resistance in Doppler ultrasound of the transplanted kidney had a significantly higher IAP mean. There was also a significant correlation between the Doppler ultrasound index and IAP (1-4) (P= 0.01) (z= -2.19) (Table 2).

The IAP increase, in comparison with Doppler ultrasound, could predict renal dysfunction with 90% of sensitivity, the negative predictive value of 94%, specificity of 45%, and positive predictive value of 22% (Figure3). Following the evaluation of renal dysfunction, the patients' IAP means were compared using Mann-Whitney test, based on the Thymoglobulin intake index as a dichotomous variable. The results indicated that the patients who received Thymoglobulin had a higher IAP mean, and Thymoglobulin index was also significantly correlated with IAP (1-4) (P= 0.003) (z= -2.91). (Table 2)

Discussion

The present study aimed to determine the diagnostic accuracy of the IAP measurement method via bladder catheter to predict renal dysfunction in patients who had kidney transplantation; therefore, renal dysfunction relied on different specific indices. In this regard, the discussion section would revolve around the main objective of determining the diagnostic value of IAP measurement through bladder catheter to predict the incidence of renal dysfunction.

In general, the finding of the current study pointed out that most of the patients had normal IAP, and

nobody experienced ACS. The rate of elevated IAP was obtained at 9.5% in the present study. Moreover, the results of this study indicated that the rate of renal dysfunction was low (15%) among 135 patients. Consistent with the findings of this study about the incidence rate of IAH and ACS, in their research, Murphy et al. (2018) conducted a study on 285 patients admitted to intensive care and surgical intensive care units. The rate of elevated IAP was up to 30% upon admission and 15% 24 h after admission; moreover, the incidence of ACS was reported as 3% (14).

Malbrain (2015) in a study on 256 patients admitted to 14 surgical intensive care units in five countries reported a rate of 65% for IAP elevation and a rate of 5% for ACS (12). According to a study performed by Coca et al. (2018) on 30 patients with Penetrating Abdominal Trauma (PAT), IAP elevation was reported to be 32%, and ACS was obtained at approximately 14%-15% (19). Consequently, based on a comparison made between the results of this research and studies by Malbrain et al. (12), Murphy et al.(14), and Tiwari et al.(20), it can be concluded that the IAP elevation rate in kidney transplant patients is less than those who experienced abdominal trauma or surgeries. This result can be justified on the ground that patients in the present study were candidates for kidney transplantation, and their hemodynamic and abdominal complications status were under control according to surgical conditions.

Acute IAH exerts adverse effects on the cardiovascular system, reduces the cardiac output and venous return and blood flow to the mesenteric vein, stimulates the renin-angiotensin system. Consequently, it results in the contraction of the arterioles and renal vein, reduction of renal blood flow, and increase of hydrostatic pressure of the Bowman's capsule, which in turn, reduces the glomerular filtration rate and decreases the urine volume. According to various studies, an inverse correlation has been found between higher IAP and urine volume (11, 21, 22). The results from data analysis pointed to a significant correlation between the adequacy of urine volume and IAP.

In agreement with the present study, Murtaza (2015) reported the reduction of urine volume to less than 25 cc/h as a complication of IAP elevation in the renal system in patients hospitalized in internal wards. Moreover, in their study, patients with higher IAP had more complications than other participants (13). Despite the differences in the research population, the mentioned study reported results which were consistent with the present research, reflecting the reduction of renal blood flow and glomerular filtration rate in the presence of IAP increase. In addition to reporting the incidence of IAP elevation in kidney transplant patients in the present study, we investigated the diagnostic value of this method in kidney transplant patients and sought to explain the predictive power of renal dysfunction by examining the sensitivity and negative predictive value of IAP measurement method.

Moreover, the results of data analysis indicated a significant relationship between delayed graft function and IAP. The results also suggested that the variables of renal dysfunction (e.g., creatinine deduction and the need for dialysis in the first week of transplantation) were significantly correlated with IAP elevation; that is to say, patients with IAP elevation experienced one or all of the variables of renal dysfunction.

The results of the data analysis also pointed to a significant relationship between the creatinine depletion of less than 25% of baseline and IAP in the first week of transplantation. The incidence rate of creatinine depletion of less than 25% of baseline in the first week of transplantation was 15% (20 out of 135 patients). Patients with creatinine depletion less than 25% of baseline experienced a higher IAP mean. In a study by Biancofiore on 108 liver transplant patients, the incidence rate of IAP elevation, along with renal insufficiency (creatinine increase), was reported to be 16%, while an increase of 32% was reported in IAP(23). Despite the difference in the research population, Biancofiore et al. reported the acceptable creatinine depletion to be less than 1.13mg/dl on the first three days after liver transplantation. They further determined the incidence rate of renal dysfunction within this range, whereas the present study examined renal transplant patients during the first week of transplantation. The incidence rate of renal dysfunction in the study by Biancofiore was in agreement with the value obtained in the present study (23).

Furthermore, the results of data analysis indicated a significant relationship between the incidence of dialysis and IAP. The incidence of dialysis due to renal insufficiency was 9% (12 out of 135 patients who required dialysis). The IAP mean was higher in patients in need of dialysis, as compared to that in other patients. In the study by Biancofiore (23), 2.7% of patients needed dialysis (3 out of 108 patients).

Furthermore, the data analysis found a significant correlation between Doppler ultrasound and IAP. It

signifies that the incidence of increased vascular resistance in vascular Doppler ultrasound of transplanted kidneys was 9.5% (13 cases out of 135 patients) in the present study. Patients with higher vascular resistance in Doppler ultrasound experienced higher IAP on average, in comparison with other patients. According to a study by Coca (2018) on 41 kidney transplants from brain dead patients, there was a significant relationship between Doppler ultrasound of the transplanted kidney and higher IAP (19). In their study, despite a smaller sample size, there was a significant relationship between Doppler ultrasound and higher IAP.

Thymoglobulin intake was a further result obtained from the evaluation of predicting renal adequacy in renal transplant patients. The rate of using Thymoglobulin due to the probability of renal dysfunction was 41.9% (57 out of 135 patients), and there was a significant relationship between IAP and Thymoglobulin intake. Nevertheless, the patients who took Thymoglobulin experienced higher IAP on average than other patients. In their review study, Alatab et al. (24) investigated the therapeutic effect of Thymoglobulin on patients prone to transplant rejection. A retrospective study on high-risk patients indicated that the long-term survival of the transplanted organ was better in patients who received Thymoglobulin, as compared to that in the control group (24) (P= 0.03).

As evidenced by the result of the present study, it can be concluded that the IAP measurement diagnostic test via bladder is a test with high sensitivity and negative predictive value for kidney transplant patients. Among the notable limitations of this study, we can refer to the frequencies of IAP measurement. The measurement of IAP during the first three days could provide more precise data. On the other hand, one of the strengths of this study was measuring the IAP of kidney transplant patients in two countries.

Implications for Practice

The results of the present study revealed that IAP measurement via bladder catheter was a nursing diagnostic method that could be performed by trained nurses to predict renal dysfunction early before any complications. Ultrasound is a diagnostic method that requires appropriate equipment and expertise. Nonetheless, IAP measurement is an easy, accurate, and accessible method which can be continuously performed by nurses during the first days of transplantation. Moreover, it can help the transplant team to diagnose early renal dysfunction with regard to creatinine, urinary, and IAP changes. Furthermore, IAP measurement has a high diagnostic value (98% of sensitivity) in the prediction of desirable creatinine depletion within a week after surgery.

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Conflicts of Interest

The authors declare that they have no conflict of interest regarding the present study.

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