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Finding new indicators for operation and angiographic embolization in blunt renal injury patients: a single-center experience over 13 years

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Purpose: Traumatic kidney injury can be treated surgically or nonsurgically. Nonsurgical treatment options include angiography, embolization, and conservative treatment. We aimed to identify factors that help in making clinical decisions on treatment plans for patients with traumatic kidney injury caused by blunt trauma.
Methods: The study included 377 patients aged ≥18 years with traumatic kidney injury caused by blunt abdominal trauma admitted to the emergency room of Wonju Severance Christian Hospital between January 2008 and July 2020. Medical records, laboratory test results, and computed tomography results were retrospectively reviewed.
Results: Multivariable logistic analysis showed diastolic blood pressure at admission and disruption of Gerota's fascia were significantly associated with surgical treatment, and that perinephric hematoma rim distance was the only significant indicator favoring embolization. Receiver operating characteristic curve analysis showed that angiography and embolization should be considered when hematoma size exceeds 2.97 cm.
Conclusion: When a patient with traumatic kidney injury due to blunt trauma visits an emergency room, even when vital signs are stable, Gerota's fascia should be checked by computed tomography prior to deciding on surgical treatment, and angiographic embolization should be considered if perinephric hematoma rim distance exceeds 2.97 cm.
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Key Words: Abdominal injuries, Embolization, Gerota's fascia, Hematoma, Laparotomy

INTRODUCTION

Approximately 80%–90% of kidney injuries are caused by blunt trauma, and these injuries account for approximately 10% of all abdominal traumas [1-3]. The majority of these kidney injuries are minor and are successfully managed by conservative treatment [4,5]. However, in 20%–40% of patients, extensive kidney damage may be present [2]. In patients with extensive injuries when the renal pedicle is damaged, surgical treatment should be performed. In other cases, surgical treatment is traditionally considered in patients with grade IV injury or higher according to the organ injury scale of the American Association for the Surgery of Trauma (AAST) and vital signs at admission. However, these treatment guidelines are no

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longer used. Over recent years, treatment policies for traumatic kidney injury have transitioned toward surgical minimalism and nonoperative management [6]. Although nonoperative treatment is accepted as the standard for low-grade traumatic kidney injury, the treatment for high-grade traumatic kidney injury remains controversial. Some authors have concluded that prompt surgical treatment reduces complications and mortality, and the possibility of late nephrectomy during follow-up [7,8]. However, several recent studies have reported successful nonoperative treatment of patients with high-grade blunt kidney injury [3,9,10]. In other words, current indications for surgery have become less clear.

Operative and nonoperative methods can be used to treat traumatic kidney injury, and nonoperative treatments may be classified as angiographic embolization or conservative treatment. Conservative treatment is aimed at stopping hemorrhage due to trauma through close observation, bed stabilization, blood transfusion, and fluid therapy without invasive procedures. Advancements in angiography are the main reason for the increased popularity of nonoperative treatments. Angiographic embolization is known to be safe and effective for liver or spleen injury [11,12], and several studies have indicated that angiographic embolization provides effective means of treating traumatic kidney injury [13,14]. However, it should be noted that the kidneys are surrounded by Gerota's fascia, which is a rigid, high-tensile, elastic structure that helps stop renal bleeding by self-tamponade when traumatic kidney injury occurs [15,16]. Therefore, even when extravasation of contrast agent is observed by CT after injury, no extravasation of contrast may be observed angiographically due to the protective effect of Gerota's fascia, and in such cases, embolization is not required.

In this background, we aimed to determine the indications for surgical treatment of traumatic kidney injury based on clinical characteristics at initial presentation, results of laboratory tests and radiological findings, and to identify the indicators for angiographic embolization by analyzing clinical characteristics, laboratory test results, and radiological findings.

METHODS

Patient selection

Three hundred and ninety-one patients with traumatic kidney injury caused by blunt abdominal trauma aged ≥18 years admitted at Wonju Severance Christian Hospital between January 2008 and July 2020 were initially considered for this study. Medical records, laboratory test results, and CT results were retrospectively reviewed. Fourteen patients with incomplete medical records or who did not undergo CT were excluded, and thus, 377 patients were included in the analysis. Twenty-eight of the 377 underwent emergency laparotomy, and 325 were treated conservatively. Angiography was performed in 24 patients, and of these, 11 received embolization and 13 underwent angiography only without embolization (Fig. 1).

Treatment of traumatic kidney injury

Fluid therapy was provided immediately to all patients and blood transfusion was performed if necessary. Hypovolemic shock patients that did not respond to fluid therapy and blood transfusions were immediately transported to the operating room after a basic examination in the emergency room and underwent emergency laparotomy. Other patients underwent CT in the emergency room. Surgical treatment was considered if vital signs were ambiguous after a CT scan, abdominal

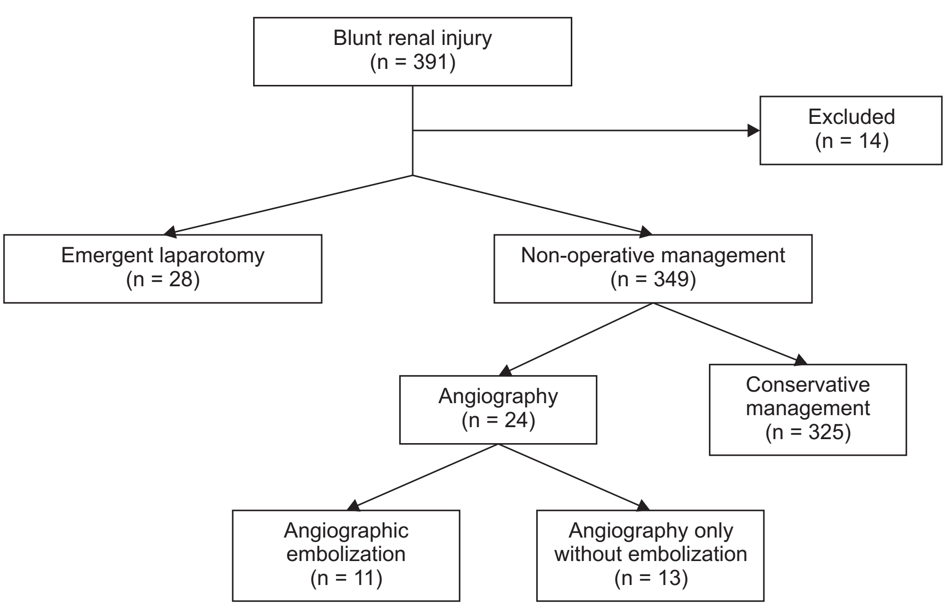

Fig. 1. Patient selection algorithm.

symptoms worsened, or extensive damage was observed by CT. Angiography was performed if vital signs remained stable but contrast extravasation was observed by CT. Patients that responded to fluid therapy and blood transfusions, and whose CT images did not clearly show extravasation of contrast were admitted to the intensive care unit (ICU) for conservative treatment.

Definitions of terms and data collection

Perinephric hematoma rim distance, laceration size, contrast extravasation, Gerota's fascia discontinuity, multiple lacerations, devitalized renal segment, dissociated renal fragment, complexity of laceration, and main laceration site were determined by abdominal CT at admission. Perinephric hematoma rim distance was defined as the longest distance between the renal capsule and the outer hematoma boundary [17]. When multiple lacerations were present, the length of the longest laceration was measured. Contrast extravasation indicated overt bleeding and was defined as the diffusion of contrast agent from the vascular into the extravascular space. Gerota's fascia discontinuity, suggesting rupture of Gerota's fascia, was confirmed if its structural continuity was lost on CT images. Multiple lacerations were defined as ≥2 lacerations in 1 or both kidneys. A devitalized renal segment was defined as loss of contrast enhancement in a portion of a damaged kidney. A dissociated renal fragment was defined as the separation of a kidney fragment from a damaged kidney, and if the shape of the kidney laceration was complicated and did not appear linear, it was considered a complexity of laceration. Main laceration sites were classified as lateral or medial based on their positions relative to a line drawn vertically through the renal hilus (blue line in Fig. 2) perpendicular to a line drawn along the renal blood vessel axis (dashed line in Fig. 2).

The following data were retrospectively reviewed; patient information (age, sex, injury severity score [ISS], associated injuries, systolic and diastolic blood pressures, pulse rate, use of antiplatelet drugs, and presence of gross hematuria), laboratory test results (delta neutrophil index [DNI], lactate, hemoglobin, and creatinine levels), blood transfusion requirements, renal injury grades (according to AAST guidelines), abdominal CT findings (perinephric hematoma rim distance, laceration size, contrast extravasation, Gerota's fascia discontinuity, multiple lacerations, devitalized renal segment, dissociated renal fragment, complexity of laceration, and main laceration site; all documented at admission), length of hospital stay, length of ICU stay, and mortality. The Institutional Review Board of Wonju Severance Christian Hospital approved the study protocol (No. CR320134). Written informed consent was waived because this study was conducted retrospectively.

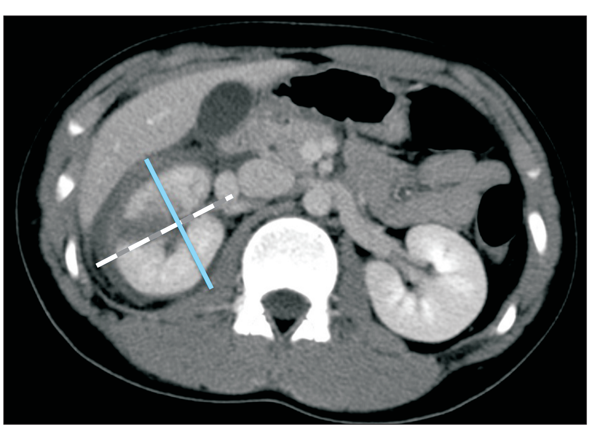

Fig. 2. Main laceration sites were divided into medial and lateral parts as indicated by the blue line. Dashed line was drawn along the renal blood vessel axis.

Statistical analysis

Continuous variables are expressed as mean values ± standard deviations. Univariate analysis of continuous variables was performed using the Mann-Whitney test, and nominal variables were analyzed using the chi-square test and Fisher exact test. In order to identify independent risk factors indicating the need for a surgical procedure, we included variables significantly associated with the surgical procedure by univariate analyses in the multivariate logistic regression analysis. Multivariate logistic regression analysis was performed to identify factors predicting embolization in patients who underwent angiography using variables presumed to be associated with embolization, such as systolic blood pressure, diastolic blood pressure, kidney injury grade of ≥IV, discontinuity of Gerota's fascia, and perinephric hematoma rim distance. A receiver operating characteristics (ROC) curve was plotted to determine the predictive value of perinephric hematoma rim distance and an optimum cutoff value. The statistical analysis was performed using IBM SPSS Statistics ver. 25.0 (IBM Corp., Armonk, NY, USA), and statistical significance was accepted for P-values of <0.05.

RESULTS

Emergency laparotomy was performed in 28 of the remaining 377 patients. Angiography was performed in 24, and of these, 11 underwent embolization. In the remaining 13 patients, contrast extravasation was observed by CT performed prior to angiography but was not noted by angiography; and hence, procedures were completed without embolization. Three hundred twenty-five patients were treated conservatively.

Univariate analysis of patients managed nonoperatively or operatively

Univariate analysis was performed to compare and analyze the details of patients who did not undergo and those who did. The analysis showed no significant difference between the 2 groups in terms of age (45.2 ± 20.8 years *vs.* 41.8 ± 17.1 years, P = 0.369) and male sex (237 [67.9%] *vs.* 21 [75.0%], P = 0.530). However, a significant intergroup difference was observed between ISSs (17.5 ± 8.9 *vs.* 25.8 ± 10.9, P < 0.001). No significant intergroup difference was found between associated injuries with an abbreviated injury scale score of ≥3 (204 [58.5%] *vs.* 13 [46.4%], P < 0.235). Mean systolic blood pressure (119.07 ± 30.94 mmHg *vs.* 82.43 ± 48.64 mmHg, P < 0.001) and diastolic blood pressure (70.31 ± 19.54 mmHg *vs.* 49.07 ± 31.56 mmHg, P < 0.001) at the initial presentation were significantly lower for patients who underwent surgery. Gross hematuria at the time of visit (110 [31.5%] *vs.* 18 [64.3%], P < 0.001) was significantly greater in patients who underwent surgery. Laboratory results showed lactate (3.15 ± 2.14 mmol/L *vs.* 5.53 ± 4.85 mmol/L, P = 0.005), and creatinine (0.96 ± 0.55 mg/dL *vs.* 1.23 ± 0.51 mg/dL, P = 0.002) levels were significantly higher in the operation group. Hemoglobin (12.9 ± 2.1 g/dL *vs.* 11.4 ± 3.0 g/dL, P = 0.010) level was significantly lower in the operation group. The 24-hour transfusion requirement (2.12 ± 5.5 units *vs.* 11.61 ± 12.1 units, P < 0.001) was also significantly higher in the operation group. In addition, the percentage of patients with a kidney injury grade of ≥IV according to AAST guidelines was significantly higher in the operation group (38 [10.8%] *vs.* 20 [71.4%], P < 0.001). The following CT findings were statistically significant in the operation group compared to the nonoperation group; perinephric hematoma rim distance (1.49 ± 1.67 cm *vs.* 3.35 ± 1.46 cm, P < 0.001), laceration size (1.74 ± 1.61 cm *vs.* 3.70 ± 1.53 cm, P < 0.001), contrast extravasation (69 [19.8%] *vs.* 24 [85.7%], P < 0.001), Gerota's fascia discontinuity (6 [1.7%] *vs.* 20 [71.4%], P < 0.001), presence of multiple lacerations (104 [29.8%] *vs.* 16 [57.1%], P = 0.002), dissociated renal fragment (36 [10.4%] *vs.* 13 [39.2%], P < 0.001), and complexity of lacerations (115 [32.9%] *vs.* 18 (64.3%], P < 0.001) (Table 1).

Table 1. Univariate analysis results of the nonoperative and operative management groups

Characteristic	Nonoperative group	Operative group	P-value
No. of patients	349	28	
Age (yr)	45.2 ± 20.8	41.8 ± 17.1	0.369
Male sex	237 (67.9)	21 (75.0)	0.530
Injury severity score	17.5 ± 8.9	25.8 ± 10.9	<0.001
Associated injury ≥ 3	204 (58.5)	13 (46.4)	0.235
Initial SBP (mmHg)	119.07 ± 30.94	82.43 ± 48.64	<0.001
Initial DBP (mmHg)	70.31 ± 19.54	49.07 ± 31.56	<0.001
Initial pulse rate (beat/min)	88.54 ± 22.90	80.82 ± 41.18	0.958
History of antiplatelet agent intake	22 (6.3)	0 (0)	0.388
Gross hematuria at presentation	110 (31.5)	18 (64.3)	0.001
Initial DNI (%)	1.19 ± 1.9	2.18 ± 5.8	0.846
Initial lactate (mmol/L)	3.15 ± 2.14	5.53 ± 4.85	0.005
Initial hemoglobin (g/dL)	12.9 ± 2.1	11.4 ± 3.0	0.010
Initial creatinine (mg/dL)	0.96 ± 0.55	1.23 ± 0.51	0.002
Blood transfusion (unit)[a]	2.12 ± 5.5	11.61 ± 12.1	<0.001
Kidney injury grade ≥ IV[b]	38 (10.9)	20 (71.4)	<0.001
Radiologic finding			
Perinephric hematoma rim distance (cm)	1.49 ± 1.67	3.35 ± 1.46	<0.001
Laceration size (cm)	1.74 ± 1.61	3.70 ± 1.53	<0.001
Contrast extravasation	69 (19.8)	24 (85.7)	<0.001
Gerota's fascia discontinuity	6 (1.7)	20 (71.4)	<0.001
Multiple laceration	104 (29.8)	16 (57.1)	0.002
Devitalized renal segment	88 (25.2)	11 (39.3)	0.058
Dissociated renal fragment	36 (10.4)	13 (46.4)	<0.001
Complexity of laceration	115 (32.9)	18 (64.3)	<0.001
Main laceration site (medial)	172 (49.3)	20 (71.4)	0.128
Length of hospital stay (day)	30.3 ± 37.2	30.9 ± 46.6	0.313
Length of ICU stay (day)	10.59 ± 17.0	9.15 ± 13.8	0.724
Mortality	26 (7.4)	8 (28.6)	0.002

Values are presented as number only, mean ± standard deviation, or number (%).
SBP, systolic blood pressure; DBP, diastolic blood pressure; DNI, delta neutrophil index; ICU, intensive care unit.
[a]Units during the first 24 hours. [b]American Association for the Surgery of Trauma-organ injury scale.

Multivariate analysis of the nonoperation group and operation group

Multivariate logistic regression analysis of risk factors for surgery showed that mean diastolic blood pressure at the time of visit was significantly lower in the operation group (odds ratio [OR], 0.957; 95% confidence interval [CI], 0.927–0.987; P = 0.006) and that the prevalence of Gerota's fascia discontinuity was significantly higher (OR, 41.079; 95% CI, 7.895–213.746; P < 0.001) in operation group. On the contrary, perinephric hematoma rim distances were not significantly different (OR, 0.670; 95% CI, 0.423–1.060; P = 0.087) (Table 2).

Correlation between CT findings

Gerota's fascia discontinuity and other CT findings were compared. Gerota's fascia discontinuity was significantly associated with other CT findings except main laceration site (medial); perinephric hematoma rim distance (1.44 ± 1.59 cm *vs.* 4.02 ± 1.66 cm, P < 0.001), laceration size (1.74 ± 1.60 cm *vs.* 3.90 ± 1.44 cm, P < 0.001), contrast extravasation (68 [19.4%] *vs.* 25 [96.2%], P < 0.001), presence of multiple lacerations (101 [28.8%] *vs.* 19 [73.1%], P < 0.001), devitalized renal segment (88 [25.1%] *vs.* 11 [42.3%], P = 0.028), dissociated renal fragment (35 [10.0%] *vs.* 14 [53.8%], P < 0.001), and complexity of laceration (133 [37.9%] *vs.* 20 [76.9%], P < 0.001) (Table 3).

Table 2. Multivariate analysis results of the nonoperative and operative management groups

Variable	Risk factor for operation	
	Odds ratio (95% CI)	P-value
Initial DBP	0.957 (0.927–0.987)	0.006
Perinephric hematoma rim distance	0.670 (0.423–1.060)	0.087
Gerota's fascia discontinuity	41.079 (7.895–213.746)	<0.001

DBP, diastolic blood pressure; CI, confidence interval.

Univariate analysis of patients who underwent angiography without or with embolization

Mean perinephric hematoma rim distance (2.76 ± 1.30 cm *vs.* 4.67 ± 2.20 cm, P = 0.016) was found to be significantly greater in the embolization group. No significant intergroup difference was observed for patients with a kidney injury grade of ≥IV (3 [23.1%] *vs.* 2 [18.2%], P > 0.999). Contrast extravasation (13 [100%] *vs.* 11 [100%]) was observed in all patients in both groups (Table 4).

Multivariate analysis of patients who underwent angiography without or with embolization

Variables included in the analysis were systolic and diastolic blood pressure at the initial presentation, AAST grade (i.e., kidney injury of grade of ≥IV), rupture of Gerota's fascia, and perinephric hematoma rim distance. Multivariate analysis showed that only perinephric hematoma rim distance was significantly associated with the need for embolization (OR, 1.921; 95% CI, 1.050–3.515; P = 0.034).

Receiver operating characteristics curve analysis of perinephric hematoma rim distance

A ROC curve was plotted to evaluate the predictive value of perinephric hematoma rim distance for embolization and the area under the curve was 0.790 (95% CI, 0.595–0.986; P = 0.016). The optimal cutoff value of rim distance that best predicted the need for embolization was 2.97 cm (sensitivity, 81.2%; specificity, 65.2%) (Fig. 3).

DISCUSSION

When a patient with traumatic blunt abdominal injury visits an emergency room, a treatment plan should be established according to the patient's clinical features and examination results, and it should be determined whether conservative treatment, emergency laparotomy, or angiography and embolization is required. Classically, clinical kidney injury AAST grade and vital signs were considered primary indicators

Table 3. Correlation between computed tomography findings

Variable	Intact Gerota's fascia (n = 351)	Ruptured Gerota's fascia (n = 26)	P-value
Perinephric hematoma rim distance (cm)	1.44 ± 1.59	4.02 ± 1.66	<0.001
Laceration size (cm)	1.74 ± 1.60	3.90 ± 1.44	<0.001
Contrast extravasation	68 (19.4)	25 (96.2)	<0.001
Multiple lacerations	101 (28.8)	19 (73.1)	<0.001
Devitalized renal segment	88 (25.1)	11 (42.3)	0.028
Dissociated renal fragment	35 (10.0)	14 (53.8)	<0.001
Complexity of laceration	133 (37.9)	20 (76.9)	<0.001
Main laceration site (medial)	172 (49.0)	20 (76.9)	0.058

Values are presented as mean ± standard deviation or number (%).

Table 4. Univariate analysis of patients that underwent angiography with or without embolization

Characteristic	Angiography		P-value
	Without embolization	With embolization	
No. of patients	13	11	
Age (yr)	43.6 ± 15.1	47.6 ± 20.3	0.622
Male sex	7 (53.8)	7 (63.6)	0.697
Injury severity score	19.4 ± 9.5	18.5 ± 11.0	0.816
Associated injury ≥ 3	6 (46.2)	5 (45.5)	>0.999
Initial SBP (mmHg)	117.31 ± 29.47	113.00 ± 34.19	0.908
Initial DBP (mmHg)	69.85 ± 21.75	69.27 ± 23.20	0.885
Initial pulse rate (beat/min)	87.46 ± 23.07	83.00 ± 19.18	0.728
History of antiplatelet agent intake	0 (0)	0 (0)	NC
Gross hematuria at presentation	5 (38.5)	7 (63.6)	0.214
Initial DNI (%)	0.92 ± 1.3	0.45 ± 0.8	0.619
Initial lactate (mmol/L)	3.50 ± 3.41	3.08 ± 2.76	0.804
Initial hemoglobin (g/dL)	11.9 ± 2.2	12.2 ± 1.6	0.450
Initial creatinine (mg/dL)	0.91 ± 0.30	1.75 ± 2.56	0.378
Blood transfusion (unit)[a]	1.69 ± 3.6	3.64 ± 6.7	0.654
Kidney injury grade ≥ IV[b]	3 (23.1)	2 (18.2)	>0.999
Radiologic finding			
Perinephric hematoma rim distance (cm)	2.76 ± 1.30	4.67 ± 2.20	0.016
Laceration size (cm)	2.47 ± 1.39	3.38 ± 1.49	0.246
Contrast extravasation	13 (100)	11 (100)	NC
Gerota's fascia discontinuity	0 (0)	1 (9.1)	0.458
Multiple laceration	7 (53.8)	6 (54.5)	>0.999
Devitalized renal segment	5 (38.5)	5 (45.5)	>0.999
Dissociated renal fragment	3 (23.1)	5 (45.5)	0.390
Complexity of laceration	7 (53.8)	8 (72.7)	0.423
Main laceration site (medial)	8 (61.5)	9 (81.8)	0.640
Length of hospital stay (day)	20.7 ± 17.2	27.3 ± 16.7	0.173
Length of ICU stay (day)	6.67 ± 5.7	5.91 ± 3.2	0.711
Mortality	1 (7.7)	2 (18.2)	0.576

Values are presented as number only, mean ± standard deviation, or number (%).
SBP, systolic blood pressure; DBP, diastolic blood pressure; DNI, delta neutrophil index; NC, not checkable; ICU, intensive care unit.
[a]Units during the first 24 hours. [b]American Association for the Surgery of Trauma-organ injury scale.

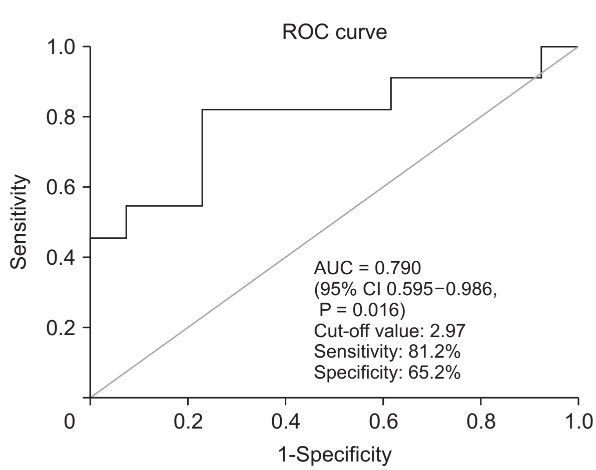

Fig. 3. Receiver operating characteristic (ROC) curve analysis of the need for angiography with embolization using perinephric hematoma rim distance.

for surgery, but nonsurgical treatment has recently become the preferred management for traumatic kidney injury, and as a result, indications for a surgical procedure have become somewhat unclear. Therefore, in this study, we aimed to identify clinical signs, laboratory and radiological findings that guide decision making. Angiography is indicated when contrast extravasation is observed by CT, but in some patients, contrast extravasation may be observed by initial CT but not by angiography, which suggests arterial occlusion or self-tamponade. Furthermore, it is difficult to determine whether time-consuming angiography is mandatory. Accordingly, we also sought to identify patient characteristics indicating a requirement for angioembolization after traumatic kidney injury.

When we examined AAST organ injury grades, which play a key role in traditional surgical guidelines, univariate analysis showed a significant association between kidney injury grade

≥IV and emergency laparotomy, but this association was not significant by multivariate analysis, which suggested a nonsurgical procedure was sufficient in some patients with high-grade injury. In addition, AAST grades were also not significantly associated with angiography and embolization by univariate or multivariate analysis.

In this study, discontinuity of Gerota's fascia and low diastolic blood pressure were independent risk factors for surgery. Decreased diastolic pressure is a known indication for surgery. Gerota's fascia is composed of rigid fibrous and fatty tissues that surround the kidney [16]. It is a hard and elastic connective tissue that is continuous with the subperitoneal fascia. Therefore, if overt bleeding occurs in the Gerota's fascia, hemostasis can be expected due to the compressive effect. However, if Gerota's fascia is damaged, compression will not occur and the hematoma will leak into the peritoneal cavity and cause persistent blood loss; hence, additional treatment will be required. Charbit et al. [18] presented Gerota's fascia as a meaningful anatomical structure that prevents bleeding around the kidney, and Fu et al. [16] concluded damage to Gerota's fascia is a radiological risk factor that indicates the need for angiographic embolization. In this study, damage to the Gerota's fascia was found to be a significant risk factor for emergency laparotomy. However, no significance was observed for angiographic embolization.

Recent studies on treatment strategies for traumatic kidney injury have highlighted the importance of contrast media extravasation among radiological findings. Lee et al. [19] reported that contrast extravasation indicates the need for urological intervention among pediatric patients with grade 4 traumatic kidney injury, and Charbit et al. [18] reported that diagnostic angiography and embolization are unnecessary if no contrast extravasation is observed. Dugi et al. [20] also found contrast extravasation favors immediate intervention. In our study, contrast extravasation as determined by CT was significantly associated with the need for surgery by univariate analysis, but not by multivariate analysis. Contrast extravasation is unquestionably an important radiological finding, but it should be noted in some patients with contrast extravasation immediate surgery is not required, probably due to the protective effect of Gerota's fascia. In the nonoperation group of our study, 69 patients showed contrast extravasation. Among these patients, 24 patients underwent angiography and 45 patients were managed with conservative management with observation only. It is because conservative management with observation only was attempted in our center when the vital sign was stable, the abdominal symptoms were mild, and the amount of extravasation on CT was small even if extravasation was observed on CT.

When a kidney laceration site is divided laterally and medially for the analysis, the possibility of additional treatment due to bleeding or urine leakage may increase if the major damage was located in the medial kidney. This is because the blood vessels in medial side of the kidney are larger in diameter and the renal pelvis, which houses the ureter. Dugi et al. [20] also reported that patients may require immediate intervention such as an emergent operation when the major injury site is medially located. However, in the present study, renal laceration site did not appear to be a significant risk factor for emergency laparotomy and embolization.

Although hematoma size was not considered a major finding in the past, many recent studies have emphasized that hematoma size be considered when deciding on a treatment plan. Charbit et al. [18] reported angiography is unnecessary when the size of a perinephric hematoma rim distance is smaller than 2.5 cm, and Dugi et al. [20] advocated immediate care be provided to prevent life-threatening bleeding when a perinephric hematoma rim distance exceeds 3.5 cm. In our study, univariate analyses showed that perinephric hematoma rim distance was significantly associated with the need for emergency laparotomy and embolization, and though perinephric hematoma rim distance was significantly associated with angiographic embolization by multivariate analysis, it was not significantly associated with emergency laparotomy. Hence, our findings suggest that perinephric hematoma rim distance can be used as a predictor of the need for angiographic embolization. ROC analysis showed angiographic embolization should be considered when the perinephric hematoma rim distance is ≥2.97 cm.

When designing this study, we expected that radiological findings such as length of laceration, multiplicity and complexity of laceration, and the presence of a devitalized renal segment, and dissociated renal fragment would reflect kidney injury severity and the need for operative treatment and embolization. However, although univariate analysis showed a significant relation between CT findings and emergency laparotomy, multivariate analysis did not show a significant correlation between these factors. Furthermore, angiographic embolization was not found to be significantly associated with emergency laparotomy by univariate and multivariate analyses. In addition, this study showed these CT findings were significantly associated with Gerota's fascia discontinuity.

DNI provides a measure of degree of infection and acute inflammatory response resulting from trauma-induced tissue damage and hemorrhage, and Bang et al. [21] showed that DNI is associated with mortality during surgery among abdominal trauma patients. However, DNI was not significantly associated with emergency laparotomy and embolization in the present study.

Lactate is a byproduct of anaerobic metabolism and is used as a marker of hypoxia in shock. In patients with multiple traumas, an elevated blood lactate level at the initial presentation suggests severe injury and probabilities of complications and mortality [22]. In this study, the univariate analysis showed elevated blood lactate was significantly associated with emergency laparotomy, but this was not supported by multivariate analysis. No clear association was also found between elevated blood lactate levels and the need for embolization.

ISSs were significantly associated with emergency laparotomy by univariate analysis but not by multivariate analysis, and ISSs were not associated with embolization. Fu et al. [16] reported ISS was a risk factor of the need for embolization and of Gerota's fascia rupture. These inconsistencies may be attributed to the small sample sizes of the 2 studies.

This study has several limitations. First, its retrospective design and the inclusion of patients treated at a single center may have caused sampling bias. Second, the majority of the patients with traumatic kidney injury in this study recovered after conservative treatment only, and only a small number of patients underwent surgery or underwent angiography. Third, all decisions regarding treatment strategies were made by trauma surgeons. Therefore, selection bias could not be avoided. In addition, many clinicians were involved in treating trauma patients in the past 13 years, which may have caused inconsistencies in decision making.

In this study, diastolic blood pressure, which has been previously considered as a part of vital signs, was found to be a significant factor in terms of establishing a treatment plan. Furthermore, the study confirmed a discontinuity of Gerota's fascia and perinephric hematoma rim distance aid the establishment of treatment plans. In addition, our results support the hypothesis that Gerota's fascia discontinuity causes blood outflow into the abdominal cavity and persistent blood loss due to the absence of the self-tamponade effect of an intact Gerota's fascia and that this condition indicates surgical treatment.

To conclude, when a patient presents with traumatic kidney injury due to blunt abdominal injury, surgery should be considered when diastolic blood pressure is low and CT findings suggest the rupture of Gerota's fascia. For patients not treated surgically, angiographic embolization should be considered when the perinephric hematoma rim distance is greater than 2.97 cm.

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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REFERENCES

1. Bretan PN Jr, McAninch JW, Federle MP, Jeffrey RB Jr. Computerized tomographic staging of renal trauma: 85 consecutive cases. J Urol 1986;136:561-5.
2. Matthews LA, Spirnak JP. The nonoperative approach to major blunt renal trauma. Semin Urol 1995;13:77-82.
3. Wessells H, Suh D, Porter JR, Rivara F, MacKenzie EJ, Jurkovich GJ, et al. Renal injury and operative management in the United States: results of a population-based study. J Trauma 2003;54:423-30.
4. Goff CD, Collin GR. Management of renal trauma at a rural, level I trauma center. Am Surg 1998;64:226-30.
5. Nguyen HT, Carroll PR. Blunt renal trauma: renal preservation through careful staging and selective surgery. Semin Urol 1995;13:83-9.
6. Salem MS, Urry RJ, Kong VY, Clarke DL, Bruce J, Laing GL. Traumatic renal injury: five-year experience at a major trauma centre in South Africa. Injury 2020;51:39-44.
7. Cass AS, Luxenberg M. Conservative or immediate surgical management of blunt renal injuries. J Urol 1983;130:11-6.
8. Kristjánsson A, Pedersen J. Management of blunt renal trauma. Br J Urol 1993;72(5 Pt 2):692-6.

9. Matthews LA, Smith EM, Spirnak JP. Nonoperative treatment of major blunt renal lacerations with urinary extravasation. J Urol 1997;157:2056-8.
10. Moudouni SM, Patard JJ, Manunta A, Guiraud P, Guille F, Lobel B. A conservative approach to major blunt renal lacerations with urinary extravasation and devitalized renal segments. BJU Int 2001;87:290-4.
11. Haan JM, Bochicchio GV, Kramer N, Scalea TM. Nonoperative management of blunt splenic injury: a 5-year experience. J Trauma 2005;58:492-8.
12. Mohr AM, Lavery RF, Barone A, Bahramipour P, Magnotti LJ, Osband AJ, et al. Angiographic embolization for liver injuries: low mortality, high morbidity. J Trauma 2003;55:1077-81.
13. Breyer BN, McAninch JW, Elliott SP, Master VA. Minimally invasive endovascular techniques to treat acute renal hemorrhage. J Urol 2008;179:2248-52.
14. Vignali C, Lonzi S, Bargellini I, Cioni R, Petruzzi P, Caramella D, et al. Vascular injuries after percutaneous renal procedures: treatment by transcatheter embolization. Eur Radiol 2004;14:723-9.
15. Fanney DR, Casillas J, Murphy BJ. CT in the diagnosis of renal trauma. Radiographics 1990;10:29-40.
16. Fu CY, Wu SC, Chen RJ, Chen YF, Wang YC, Chung PK, et al. Evaluation of need for angioembolization in blunt renal injury: discontinuity of Gerota's fascia has an increased probability of requiring angioembolization. Am J Surg 2010;199:154-9.
17. Nuss GR, Morey AF, Jenkins AC, Pruitt JH, Dugi DD 3rd, Morse B, et al. Radiographic predictors of need for angiographic embolization after traumatic renal injury. J Trauma 2009;67:578-82.
18. Charbit J, Manzanera J, Millet I, Roustan JP, Chardon P, Taourel P, et al. What are the specific computed tomography scan criteria that can predict or exclude the need for renal angioembolization after high-grade renal trauma in a conservative management strategy? J Trauma 2011;70:1219-27.
19. Lee JN, Lim JK, Woo MJ, Kwon SY, Kim BS, Kim HT, et al. Predictive factors for conservative treatment failure in grade IV pediatric blunt renal trauma. J Pediatr Urol 2016;12:93.
20. Dugi DD 3rd, Morey AF, Gupta A, Nuss GR, Sheu GL, Pruitt JH. American Association for the Surgery of Trauma grade 4 renal injury substratification into grades 4a (low risk) and 4b (high risk). J Urol 2010;183:592-7.
21. Bang HJ, Kim K, Shim H, Kim S, Jung PY, Choi YU, et al. Delta neutrophil index for predicting mortality in trauma patients who underwent emergent abdominal surgery: a case controlled study. PLoS One 2020;15:e0230149.
22. Freitas AD, Franzon O. Lactate as predictor of mortality in polytrauma. Arq Bras Cir Dig 2015;28:163-6.