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A Comparative Study of Conservation, Endovascular Embolization Therapy, and Surgery for Blunt Renal Trauma

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Background: In this study, we evaluated the advantages and disadvantages of angioembolization in patients with Grade III–V blunt renal trauma compared with other treatments.

Material/Methods: We prospectively collected data on patients hospitalized for Grade III–V blunt renal trauma. Organ damage was graded according to the American Association for the Surgery of Trauma (AAST) criteria. Initial grouping was then performed according to the hemodynamics and “initial treatment”. The eligible patients were divided into 3 groups: conservative treatment group (Group A), arterial embolization group (Group B), and surgical group (Group C). The success rate, significance, and follow-up renal function were evaluated.

Results: In Group B of Grade IV, estimated glomerular filtration rate (eGFR) and serum creatinine (Scr) levels were slightly decreased and increased, respectively, after embolization compared with before embolization ($P=0.002$, $P=0.039$). In Grade V, the eGFR of Group B after embolization was lower than before embolization ($P=0.041$); The levels of serum urea (Urea) and Scr in Group B after treatment were higher than those before treatment ($P=0.042$, $P=0.024$). Conservative treatment and angioembolization were better than exploration in protecting renal function of Grade IV ($P=0.035$ and $P=0.047$, respectively).

Conclusions: The success rate of angioembolization was high and protected renal function to the greatest extent, and there were no differences in renal function at long-term follow-up. However, it is difficult to manage renal vessel laceration or avulsion by embolization alone, and various endovascular therapies are required to protect the function of residual kidneys.

MeSH Keywords: **Radiology, Interventional • Surgical Procedures, Operative • Wounds, Nonpenetrating**

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Background

Renal trauma mainly occurs secondary to fall injury, knife stab injury, road traffic accident, and iatrogenic injury (e.g., percutaneous biopsy or percutaneous nephrolithotomy). Up to 10% of patients with abdominal trauma have varying degrees of renal trauma, which is the third most common site of injury, after the spleen and liver [1]. Most traumas are caused by blunt injury [2]. Several studies have shown that there is a significant correlation between the decrease in renal function and the grade of trauma [3,4]. Conservative and angio-embolism management of Grade I–III trauma is widely accepted, but the possibility of surgical resection cannot be completely ruled out, especially in hospitals without trauma centers and in areas with poor medical facilities. High-grade blunt renal trauma (i.e., Grades IV and V) accounts for approximately 25% of all renal traumas [5], and there is still some controversy about its management. In the past, the main form of treatment was surgery, but this led to kidney loss in most cases. Non-surgical treatment is increasingly preferred to avoid nephrectomy and prevent long-term complications of renal insufficiency. The only purpose of treatment is to preserve the kidney. There were no differences in the decreases in renal function in high-grade injury subtypes (parenchymal and vascular causes) [4], but all were associated with varying degrees of decline in renal indexes [3]. Several studies have shown that high-grade injuries can be successfully treated using non-surgical methods. However, with the development of interventional endovascular technology, the rate of nephrectomy has decreased, although it remains high [6]. Interventional therapy for blunt renal trauma includes renal angioplasty, renal arterial stenting, and selective angioembolization, which are minimally invasive and associated with a high success rate. At present, interventional therapy is considered to be a second-line method after ineffective conservative treatment of Grade I–III renal trauma. Although endovascular therapy has received increasing attention, no precise indicators of the advantages of vascular intervention compared with conservative and surgical management have yet been reported. Therefore, we conducted this case-control study to investigate the advantages and disadvantages of interventional embolotherapy, conservative therapy, and surgical exploration for Grade III–V blunt renal trauma.

Material and Methods

Patients and data collection

Patients hospitalized for Grade III–V blunt renal injury from January 2011 to March 2018 were included in this study. Demographic data and serum renal function indexes before management and after treatment were prospectively collected. Hemodynamic stability was the primary criterion

for the management of all renal injuries. The following inclusion criteria were applied: (1) Patients with blunt kidney injury, the types of injuries included high fall injury and road traffic accident injury; (2) Simple kidney injury and kidney injury combined with other organs; and (3) All patients were adults. The exclusion criteria were as follows: (1) Penetrating injury, such as stab wound; (2) Aortic trauma; and (3) Children. This study was approved by our institutional Ethics Committee.

The eligible patients were divided into 3 groups according to the hemodynamics and initial treatment: conservative treatment group (Group A), arterial embolization group (Group B), and surgical group (Group C). The inclusion criteria for Group A were: hemodynamic stability and confined stable hematoma. The inclusion criteria for Group B were: patients with stable hemodynamics but persistent bleeding; hemodynamic stability but computed tomography (CT) imaging suggested central or expanding hematomas; hemodynamics was stable but there was gross hematuria; and hemodynamic instability, but family members requested interventional therapy (simple embolization or embolization combined with angioplasty). The inclusion criteria for Group C were: hemodynamic instability; expanding or pulsatile peri-renal hematoma; shattered renal parenchyma; and trauma of the renal pedicle (artery and vena) (Figure 1).

Management and follow-up

For all confirmed patients, initial management after admission included conservative treatment such as bed rest, analgesia, and fluid replacement. Arterial embolization included angioembolization, angioplasty, and stent implantation. Angioembolization included renal artery embolization or super-selective renal artery embolization, regardless of the embolic material. Surgical management refers to surgical exploration, including renal reconstruction, nephrectomy, drainage of the ipsilateral retroperitoneum, ureteral stent, and vascular repair. The goals of exploration following renal trauma were control of hemorrhage and complications and renal salvage. Conservative treatment refers to all treatment methods excluding interventional and surgical exploration.

In Groups A and Group B, clinical success was defined as that achieved by conservative treatment or angioembolization alone, excluding conversion to other treatments in the middle of the therapy. Surgical success refers to clinical success without death (Figure 1).

Active bleeding was detected in emergency CT scans, and the choice of vascular embolization or surgical exploration treatment was determined according to hemodynamics. Patients who failed in conservative and interventional treatment underwent surgical exploration. A step-by-step approach was employed for the treatment process, starting with conservatism, followed by minimally invasive and/or surgical exploration if necessary.

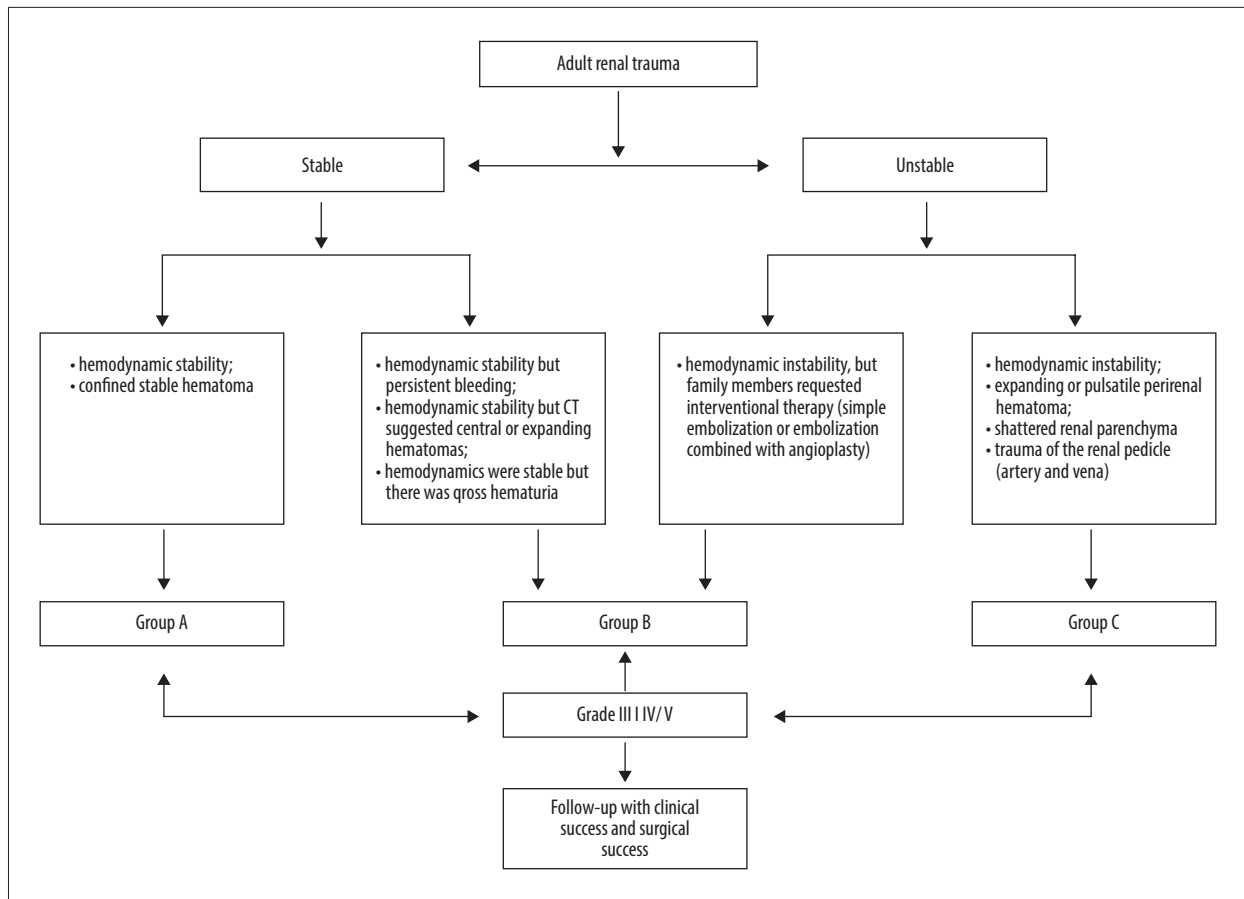


Figure 1. Flow chart of management of adult renal trauma.

Follow-up included physical examination, CT or magnetic resonance imaging (MRI), and serum renal indexes. Short-term follow-up (within 6 weeks) consisted mainly of serum renal function evaluation of indicators, including eGFR, serum urea, β 2-microglobulin (β 2-MG), and Scr. Radionuclide scans were used for long-term renal function assessment (6 months).

Statistical analysis

The IBM SPSS (version 20; IBM Corp., NY, USA) software package was used to perform the statistical analyses. Continuous variables were analyzed with independent-samples *t* tests and were expressed as the mean \pm standard deviation, while categorical variables were compared using χ^2 tests. A *P*-value of <0.05 was considered to indicate statistical significance.

Results

During the study period, 160 patients with renal injury classified as Grade III–V were included in the study. The average ages of patients in Groups A, B, and C were 35 ± 13 y, 37 ± 21 y, and 41 ± 9 y, respectively, with no significant difference among

the 3 groups ($P=0.627$ between Groups A and B; $P=0.538$ between Groups A and C; $P=0.235$ between Groups B and C). There were 105 males (64%) and 55 females (34%), with significantly more males than females ($P=0.002$) (Table 1). The types of injuries included road traffic accidents (82 cases), fall injuries (76 cases), and falls during bathing (2 cases).

Among the 160 renal trauma patients, 41 cases (19%) were classified as Grade III, 69 cases (32%) as Grade IV, and 50 cases (23%) as Grade V.

The success rates in Groups A, B, and C of Grade III were 88%, 100%, and 100%, respectively. In Grade III injury, 1 case in Group A had a progressive decrease in hemoglobin levels and was successfully treated by embolization. All patients in Group B were successfully treated by interventional embolization. In Group C, 5 patients with renal cysts (2 cases) and stones (3 cases) underwent successful nephrectomy (Table 2, Figure 2).

The success rates in Groups A, B, and C of Grade IV were 65%, 95% and 96%, respectively. The success rates in Groups B and C were higher than that in Group A ($P=0.018$ and $P=0.015$, respectively), but there was no significant difference between Group B

Table 1. Demographic data.

Patient characteristics	Total (160)	A	B	C	A and B	A and C	B and C
		Number (n=39)	Number (n=62)	Number (n=59)	P	P	P
Age, year		35±13	37±21	41±9	0.627	0.538	0.235
Sex, No. (%)	M (105, 64%)	29 (29/39, 74%)	40 (40/62, 65%)	36 (36/59, 61%)	0.445	0.263	0.721
	F (55, 34%)	10 (10/39, 26%)	22 (22/62, 35%)	23 (23/59, 39%)	0.249	0.107	0.642
P	0.002	0.000	0.003	0.028			

Data represent the mean±standard deviation. Independent-sample t-tests were used for statistical analyses.

Table 2. Grades of trauma and patient outcomes.

Grade	Total (160)	A		B		C		A and B	A and C	B and C
		Number	Success rate (%)	Number	Success rate (%)	Number	Success rate (%)	P	P	P
III	41	8 (8/41, 20%)	88 (7/8)	28 (28/41, 68%)	100 (28/28)	5 (5/41, 12%)	100 (5/5)			–
IV	69	23 (23/69, 33%)	65 (15/23)	20 (20/69, 29%)	95 (19/20)	26 (26/69, 38%)	96 (25/26)	0.018	0.015	0.944
V	50	8 (8/50, 16%)	50 (4/8)	14 (14/50, 28%)	86 (12/14)	28 (28/50, 56%)	93 (26/28)	0.002	0.000	0.601

Data were analyzed by χ^2 test.

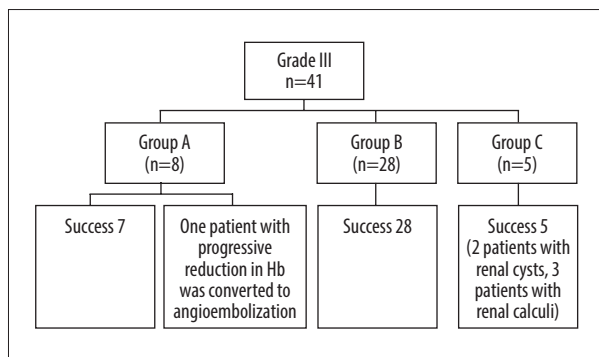


Figure 2. Flow chart of Grade III patients included in the study.

and Group C (P=0.944). In Group A, 7 failed patients were successfully treated by angioembolization due to intermittent gross hematuria, and 1 partial renal artery laceration was successfully treated by renal artery angioplasty. In Group B, 1 case had successful resection because of persistent hematuria after several attempts at embolization. In Group C, surgical treatment was carried out in 18 patients with renal parenchyma laceration and entry of the collecting system through the corticomedullary junction, and 8 patients with segmental renal artery injury with had hematoma or partial vessel laceration. However, 1 patient died of post-surgical infection (Table 2, Figure 3).

The success rates in Groups A, B, and C of Grade V were 50%, 86%, and 93%, respectively. The success rates of treatment

in Groups B and C were higher than that in Group A (P=0.002 and P=0.000, respectively), while there was no significant difference between Group B and Group C (P=0.601). Among the 4 patients who failed conservative treatment in Group A, 2 patients withdrew from conservative treatment because of pain and were successfully treated by renal embolization, and 2 patients received ureteral stents because of urinary extravasation. Two patients in Group B were successfully treated by renal angioplasty combined with embolization and ureteral stent, although only angiographic embolization patients were included in this study, so these 2 patients were considered as failure cases in this group. In Group C, 1 patient died of cerebral hernia and 1 patient died of diffuse intravascular coagulation (DIC). The success rate of patients in Group A with Grade V was lower than that of patients in Group A with Grade IV, although this difference did not reach the level of statistical significance (P=0.162, 65% vs. 50%) (Table 2, Figure 4).

Following stratification according to trauma grades III, IV, and V, serological parameters were not analyzed in the following groups: failed patients, embolization combined with angioplasty, dead patients, and initial surgical patients. Because long-term renal function depends on the contralateral kidney, in the surgical group, especially nephrectomy patients, relative function was not analyzed for these patients.

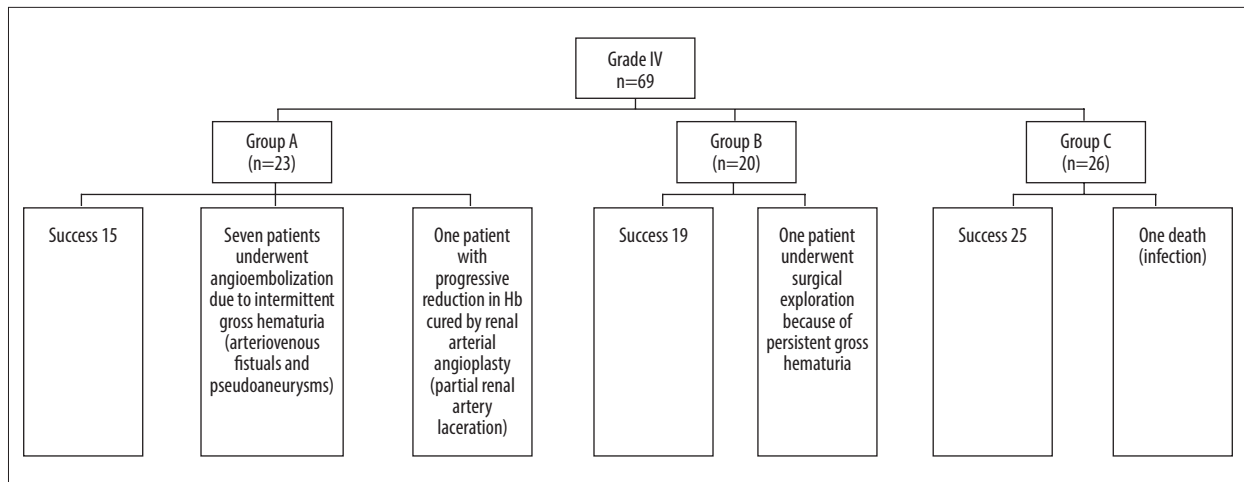


Figure 3. Flow chart of Grade IV patients included in the study.

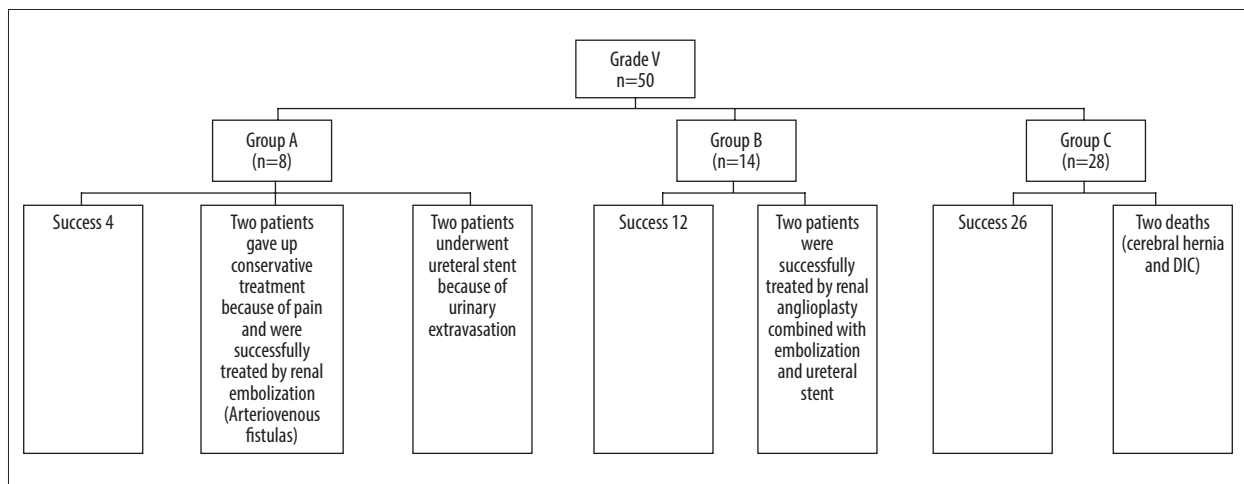


Figure 4. Flow chart of Grade V patients included in the study.

In patients with Grade III trauma, there were no significant differences in eGFR, serum urea, β 2-MG, and Scr between Group A and Group B before and after treatment. In Group B of Grade IV, eGFR and Scr exhibited a slight decrease and increase, respectively, after embolization compared with those before embolization ($P=0.002$, $P=0.039$). After corresponding treatment, Scr in Group B of Grade IV was significantly higher than that in Group A of Grade IV ($P=0.029$).

In Grade V trauma, the eGFR of Group B after management was lower than that before treatment ($P=0.041$). The levels of Urea and Scr in Group B after treatment were higher than those before treatment ($P=0.042$ and $P=0.024$, respectively). After corresponding management, eGFR in Group B of Grade V was significantly lower than that in Group A of Grade V ($P=0.020$). There were no significant differences in the other serologies (Table 3).

Due to a variety of factors, not all patients were followed up. The relative renal function values of Grade III injury after

conservative treatment and embolization were $98\pm 7\%$ and $86\pm 5\%$, respectively. After corresponding treatment, the relative renal function values in Groups A, B, and C of Grade IV trauma were $40\pm 9\%$, $35\pm 12\%$, and $23\pm 14\%$, respectively. Conservative treatment and angioembolization were significantly more successful than surgical exploration in protecting renal function of Grade IV ($P=0.035$ and $P=0.047$, respectively). Relative renal function of Grade V injury after conservative treatment, embolization, and surgery were $15\pm 17\%$, $11\pm 14\%$, and $8\pm 9\%$, respectively. Conservative treatment was significantly more successful than surgery in protecting the renal function of Grade V patients ($P=0.039$) (Table 4).

Discussion

Hemodynamic stability is the main criterion for the treatment of all grades of renal trauma. To avoid the need for nephrectomy and to prevent long-term complications such as renal

Table 3. Characteristics of serum renal function indexes in patients.

Grade	Parameters	A			B			A and B	A and B
		PRE (n=7)	POST (n=7)	P	PRE (n=28)	POST (n=28)	P	Pre-treatment	Post-treatment
III	eGFR	105.0±9.3	103.6±8.6	0.202	102.0±8.1	100.8±7.6	0.035	0.591	0.742
	Urea	3.6±0.4	3.6±0.9	0.751	3.8±0.5	4.0±0.9	0.064	0.751	0.491
	β2-MG	3.1±0.5	3.2±0.7	0.552	2.8±0.9	3.8±1.7	0.459	0.587	0.695
	Scr	94.3±10.3	92.2±5.0	0.629	94.0±8.0	95.1±6.0	0.402	0.940	0.221
IV	eGFR	81.4±9.5	79.7±10.0	0.055	80.0±8.2	77.5±6.7	0.002	0.667	0.507
	Urea	4.1±0.7	4.0±0.7	0.467	3.8±0.9	4.1±0.9	0.153	0.232	0.832
	β2-MG	3.8±1.1	4.0±1.0	0.078	3.9±0.7	4.4±1.1	0.133	0.863	0.358
	Scr	84.3±10.7	83.9±9.3	0.846	87.6±10.4	93.1±12.3	0.039	0.396	0.029
V	eGFR	80.3±3.1	81.2±10.0	0.374	78.8±11.0	72.5±5.6	0.041	0.722	0.020
	Urea	5.0±1.0	4.7±1.2	0.430	4.5±0.4	5.5±1.3	0.042	0.725	0.087
	β2-MG	4.9±1.0	5.1±1.3	0.225	5.9±0.5	6.1±1.5	0.078	0.840	0.591
	Scr	88.1±9.5	91.4±6.5	0.656	87.4±11.2	102.8.1±16.8	0.024	0.731	0.244

Data represent the mean±standard deviation. Paired sample *t*-tests and independent-sample *t*-tests were used for statistical analyses. eGFR – estimated glomerular filtration rate (mL/min/1.73 m²); Urea – serum urea (mmol/L); β2-MG – serum β2-microglobulin (mg/L); Scr – serum creatinine (μmol/L).

Table 4. Relative renal function calculated with 99mTc-DMSA and 99mTc-DTPA.

Grade	Long-term follow-up number	Post-conservative management (%)	Post-angioembolization (%)	Post-surgery (%)	A and B	A and C	B and C
					P	P	P
III	29	98±7 (n=6)	86±5 (n=23)	–	0.067	–	–
IV	45	40±9 (n=11)	35±12 (n=18)	23±14 (n=16)	0.078	0.035	0.047
V	29	15±17 (n=3)	11±14 (n=8)	8±9 (n=18)	0.179	0.039	0.352

Paired sample *t*-tests and independent-sample *t*-tests were used for statistical analyses; 99mTc-DMSA – 99mTc-dimercaptosuccinic acid; Tc-DTPA – 99mTc-diethylenetriaminepentaacetic acid.

insufficiency, non-surgical approaches are becoming increasingly popular, with techniques such as angioembolization resulting in significantly improved success rates for high-grade renal injury in recent years [7,8].

Non-surgical management of trauma Grade I–III is widely accepted. Although cortical laceration is >1 cm and the collecting system is not used in patients with Grade III injury, clinical

manifestations such as intermittent or persistent hematuria may still exist. Conservative treatment is not necessarily effective, especially in patients with complications such as arteriovenous fistula and pseudoaneurysm, which are rare complications (2.5%) after blunt renal trauma [9]. Arteriovenous fistulas and pseudoaneurysms, which may be normal on early CT, often present as intermittent or persistent hematuria, as well as central or expanding hematomas. In our study, the group A

and B, initial hemodynamics were stable, but gross hematuria and reduction in Hb were present. There was no renal vascular injury on early CT, but arteriovenous fistula and pseudoaneurysm were found on angiography. Early angiography may be more helpful in the diagnosis of vascular injury, and selective embolization is often used in these patients [8,10–12]. Simple embolization results in a lower rate of kidney loss and lower risk of infection. Partial nephrectomy can be performed if Grade III injury is complicated by other diseases of the ipsilateral kidney, such as cysts, stones, vascular malformations, and fluctuating perirenal hematoma, and no obvious abnormality of the contralateral renal function. In this study, we found that the success rate was high, and there were no differences among the 3 groups in terms of long-term follow-up of renal function of Grade III. Low-grade renal trauma and super-selective embolization have little effect on renal function, so conservative treatment is the first choice. When conservative treatment is ineffective, embolization is chosen to maximize the protection of renal function. Surgery is considered only when other diseases are involved.

Because the kidneys are commonly affected by other organ injuries, it is often difficult to make treatment decisions for high-level kidney trauma. Decisions that determine the treatment plan in such cases are based on enhanced CT and clinical manifestations of the kidney. However, the predictive factors of surgery and interventional therapy are uncertain, although surgical predictors have been suggested to include hemodynamic instability, persistent bleeding, perinephric hematoma >3.5 cm, heart rate, and Grade V injury [13–16].

If the hemodynamics of patients with Grade IV renal trauma is stable, conservative treatment and angioembolization are recommended as a priority to protect the kidney and improve long-term renal function as far as possible. Predictive factors offering a high degree of accuracy for vascular embolization therapy include active contrast medium extravasation and hematoma >2.5 cm, arteriovenous fistula, and pseudoaneurysm [8,17]. However, we believe that the indications for embolization therapy can be expanded appropriately; that is, embolization therapy can be attempted in patients with stable and unstable hemodynamics. If persistent urinary extravasation occurs, symptoms can be improved by ureteral stent placement and percutaneous renal drainage [18]. Changes in serological indicators of renal function of Grade IV trauma may be related to the embolic volume, which can lead to renal function damage in the short term. However, nuclear scintigraphy, which is recommended for long-term follow-up of renal function, showed that renal function was better protected after conservative treatment and embolization than after surgery. Even parenchymal laceration is somewhat functional after conservative treatment, which verifies that some renal function indicators differ between embolization and conservative management.

This finding is consistent with previous reports [15]. The vascular subgroup of Grade IV trauma, including segmental renal artery or vein injury, containing hematoma, partial vessel laceration, and vessel thrombosis, can be successfully treated by interventional therapy [19]. Embolization, angioplasty, and surgical exploration can be considered for patients who fail conservative treatment [20].

Grade V injury is usually characterized by hemodynamic instability, higher exploration rates, and nephrectomy [6]. However, due to improvements in surgical methods, Grade V injury (including parenchymal shattered kidney and renal pedicle avulsion) can be managed by interventional therapy. Parenchymal shattered kidney can be successfully treated by angioembolization, and renal artery avulsion can be treated by angioplasty. Ureteral stent and external drainage can be tried if urine leakage occurs, but surgical exploration must be performed in patients with ureteropelvic avulsion. Some scholars maintain that when the relative renal function is more than 10%, complete nephrectomy should not be performed [21]. For parenchymal shattered kidney of grade V, if the hemodynamics is stable, the primary task is to protect the residual kidney. However, for trauma of the renal pedicle or avulsion, hemodynamics is often unstable in such patients, so multiple endovascular management and surgical exploration are preferred [6,22]. Overall, endovascular therapies, including embolization and stenting, have a higher success rate than surgery for the treatment of Grade V trauma. In accordance with other studies, they concluded that transfusions and periods of hospitalization were fewer, although the research was limited by the absence of renal function evaluations [15,23].

The short-term renal function index changes transiently, although it does not accurately reflect residual kidney function. Renal scintigraphy has long been used for accurate measurement of the relative renal function. There are differences in the biological characteristics of radiopharmaceuticals, such as renal excretion mechanism, renal cell retention of radioactive material, level of plasma-protein bound, and level of plasma clearance [24]. Technetium-99m dimercaptosuccinic acid (99mTc-DMSA) and technetium-99m diethylenetriaminepentaacetic acid (99mTc-DTPA) are commonly-used radiopharmaceuticals and are equally reliable in calculating relative renal function [25]. Our results show that damage to renal function occurs regardless of the severity of the trauma, including the inevitable damage caused by treatment. Conservative treatment is generally better than any invasive technique in protecting renal function.

Due to incomplete data collection resulting from the nature of the patients' work and social class, it is difficult to evaluate the relative function of the injured kidney by renal scintigraphy in the long-term. In addition, the nature of medical

insurance and the opinions of family members are also important factors that influence the choice of treatment. In the angioembolization group, only the patients with simple embolization were included for comparison, and no combined endovascular therapy was performed.

Conclusions

The success rate of vascular embolization was high and provided the greatest protection of renal function, with no difference in renal function observed after long-term follow-up.

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Conflict of interests

None.