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**Non-operative versus operative management of
penetrating kidney injuries :**

A prospective audit

By

Dr Conray Moolman

Student number MLMCON002

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University of Cape town

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Supervisor : Prof R Barnes
Division of Urology
Groote Schuur Hospital
Faculty of Health Sciences
University of Cape town

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DECLARATION

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University of Cape Town

List of Acronyms and abbreviations

NOM : Non-operatively managed kidney injuries

GSW : Gunshot wounds

SW : Stab wounds

BP : Blood pressure

AAST : American Association for the Surgery Trauma

CT scan : Computerised tomography

IVP : Intravenous pyelogram

AVF : Arteriovenous fistula

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Abstract

Introduction

To date there is little data on conservative management of penetrating renal trauma. The aim of this study was to review the management and outcome of a large patient cohort presenting with penetrating renal trauma to a tertiary referral centre in South Africa.

Methods

All patients presenting with penetrating abdominal trauma and haematuria admitted to the Trauma Centre at Groote Schuur Hospital over a 19-month period was prospectively evaluated. Patients' demographics, mechanism of injury, microscopic versus macroscopic haematuria, grade of injury, management decision (non-operative, laparotomy for other reasons without renal exploration or true renal surgery with Gerotas fascia opened), non-surgical success rate, complications, hospital stay, transfusion requirements and nephrectomy rate were analysed. Patients presenting with haematuria associated with an acute abdomen underwent single-shot intravenous pyelogram prior to surgery, whereas those presenting with haematuria without any indication for laparotomy had a contrasted CT abdomen. Renal trauma was confirmed by imaging or during abdominal exploration at the time of surgery.

Results

Ninety-two patients (84 males and 8 females) presented with haematuria following penetrating abdominal trauma. There were 75 (80.4%) renal injuries

proved intra-operatively or via imaging. Median age was 26 years [range 14-51 years]. Trauma mechanism was stab wound in 50 (54.3%) and gunshot injuries in 42 cases (45.7%). Imaging modalities included CT scan in 60 (65.2%) cases and single-shot IVP in 18 (19.6%) cases. Nine patients (9.8%) were directly brought to the operating room without further imaging.

Microscopic haematuria diagnosed in 39 cases was associated with grade I, II, III, IV and V renal trauma in 5 (12.8%), 16 (41.0%), 12 (30.8%), 5 (12.8%) and 1(2.6%) patients, respectively. Overall, 18 of 39 patients (46.2%) with microscopic haematuria had grade III injury or worse. Also, 29 of 32 patients (90.6%) with macroscopic haematuria had Grade III injury or worse($p < 0.001$).

A total of 47 patients with 49 proven renal injuries (65.3%) were managed non-operatively(NOM). In this group, renal injuries was graded I, II, III, IV, and V in 6 (12.2%), 18 (36.7%), 17 (34.7%), 9 (18.4%), and 0 (0%) cases, respectively. There was 4 (8.2%)(0.02-16.1%) patients in this group that presented with delayed macroscopic haematuria after initial conservative management. Of these, 1 patient (25%) had a normal angiogram and the other 3 (75%) had successful angio-embolisation of an arteriovenous fistula (2) and a false aneurysm (1). None of the patients who were elected to undergo conservative management had any delayed surgical intervention during follow-up. The median hospital stay and blood transfusion requirements for NOM patients was, 6 days(range 1-32) and 0 units(range 0 - 7), respectively.

In the cohort of 25 patients with renal exploration, there were 18 nephrectomies (overall nephrectomy rate of 24%) performed for uncontrollable bleeding (11), hilar injuries (2), 'shattered' kidney (3) and no reason stated (2).The nephrectomy conversion rate in all patients where Gerota's fascia was surgically explored was 72%. In all, 13 nephrectomies were due to gunshot wounds (72.2%). Post-nephrectomy complications included one infected renal bed haematoma requiring percutaneous drainage. The median hospital stay and blood transfusion requirements in all patients that had surgical renal exploration was 8 days(range 1-34) and 2 units(range 0-9) respectively.

Conclusion

Penetrating abdominal trauma and concomitant haematuria is associated with a high rate of renal injury (80.4%). Even with microscopic haematuria the incidence of higher grade renal trauma (\geq grade III) is up to 46%. If the decision for renal exploration is made, the nephrectomy conversion rate is as high as 72%. Conservative management leads to a high organ preserving success rate (100%) with minimal morbidity. The median hospital stay ($p=0.009$) and transfusion requirements ($p=0.003$) was also lower in the NOM patients. This information is crucial for clinical decision making, as aggressive surgical management with renal exploration may lead to high rates of potentially preventable nephrectomies.

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Chapter 1 : Literature review

Violence in South africa

In South Africa we face an unprecedented burden of morbidity and mortality arising from violence and injury. Violence is the 2nd most leading cause of death and disability-adjusted life years lost in our country, after HIV/AIDS (1). South Africa had 59935 deaths due to injury in 2000, which is an overall death rate of 157.8 per 100 000 population. This is twice the global average (2). Violence is profoundly gendered, with young men (15-29yrs) disproportionately engaged in violence(184 per 100 000) both as victims and perpetrators. This rate is more than twice in Cape Town's townships (3). In South Africa, firearm related deaths is among the highest in the world. It is shown that 39% of male homicides are committed with guns (4). South Africa's violent history has resulted in an entrenched gun culture, with widespread access to unlicensed and stolen firearms. The fact that 3700 South African Police and Metropolitan Police firearms are lost each year just exacerbates this problem(5).

Epidemiology

The literature suggests that the number of trauma patients with confirmed renal injury ranges from 1.4-3.25% (6,7). The kidney being the most commonly injured genitourinary organ. In large retrospective studies the mean age of renal trauma is 20-30 years and is more common in males 3:1 (8,9). The majority of adult and paediatric renal injuries result from blunt mechanisms, like motor vehicle accidents, falls, assault and contact sports (6,10). In a study of 6231 patients with renal injuries, 81.6% were caused by blunt trauma (11). Gunshot wounds and stab wounds are the most common cause of all penetrating injuries. Penetrating renal injuries are associated

with more severe renal injuries and has a higher risk for other intra-abdominal injuries (12).

Classification of renal injuries

A total of 26 classifications for renal injuries have been presented in the literature over the last 50 years. The American Association for the Surgery of Trauma(AAST) score for renal injuries was validated in 2001 by a retrospective review of 2467 patients (13).

Grade	Type	Description
1	Contusion	Haematuria, investigations normal
	Haematoma	Subcapsular, not expanding
2	Haematoma	Nonexpanding perinephric hematomas confined to the retroperitoneum
	Laceration	Superficial cortical lacerations less than 1 cm in depth without collecting system injury
3	Laceration	Renal lacerations greater than 1 cm in depth that do not involve the collecting system
4	Laceration	Renal lacerations extending through the kidney into the collecting system
	Vascular	Injuries involving the main renal artery or vein with contained haemorrhage
5	Laceration	Shattered kidney
	Vascular	Avulsed renal hilum devascularised kidney

Table 1: The American Association for the Surgery of Trauma (AAST) renal injury severity scale

This classification allows accurate description of most renal injuries, although there are some shortcomings. The “shattered kidney” needs to be clarified. The interpretation of the seriousness of this injury needs to be emphasised. It should not include a kidney injury with 2 or more Grade III or IV injuries, but only the completely destroyed kidneys. In a recent paper by McAninch et al (14), a new renal injury staging system is proposed. In the “Revised Injury Staging Classification” (RISC), the interpretation of Grade IV and V injuries is addressed. Grade IV should also include *multiple* renal lacerations into the collecting system (now a large proportion of “shattered kidneys” will fall into this category), segmental renal artery/vein injuries and renal pelvis injuries. Grade V includes only main renal artery/vein laceration or avulsion or thrombosis. No mention of the “shattered kidney” is made. This new classification should lead to less Grade V injuries being diagnosed. This might lead to more renorrhaphies being performed and less automatic nephrectomies.

Workup of patient with possible renal injury

In a patient with possible renal trauma, the hemodynamic status needs to be assessed. Heart rate, systolic blood pressure and respiratory rate must be determined on arrival. All patients are then resuscitated along Advanced Trauma Life Support (ATLS®) guidelines. Indications for emergency laparotomy are peritonitis (diffuse tenderness, rebound tenderness, guarding or rigidity), hemodynamic instability, blood per rectum and abdominal Injuries with associated head and spinal cord injuries that precluded serial abdominal examination (46). If emergency laparotomy is not indicated, a detailed history with a physical examination (flank bruising/abrasions, rib fractures, entrance and exit wounds) should be done to determine if the patient needs further investigations. A high index of suspicion should accompany all penetrating injuries to the abdomen and chest. Urinalysis is mandatory on all patients with possible renal injury. Haematuria(microscopic or macroscopic) is

present in 80-95% of all renal injuries (15). There is no relationship between the degree of haematuria and the severity of renal injury (15). Major renal injuries, like renal pedicle injuries or segmental arterial thrombosis may occur without haematuria (16). Haematuria that is out of proportion to the degree of renal injury might suggest pre-existing renal pathology (77).

Radiographic imaging:

The indications for radiological imaging include:

1) Penetrating injuries

- All penetrating trauma patients with likelihood of renal injury (abdomen, flank, chest) who are haemodynamically stable.

2) Blunt injuries

- All blunt trauma with macroscopic haematuria.
- All blunt trauma with microscopic haematuria and initial hypotension (Systolic BP < 90mm/Hg) prior to resuscitation.
- All children with microscopic haematuria (52).

The goal of imaging is to accurately stage the renal injury, confirm function of opposite kidney, diagnose pre-existing renal pathologies and identify injuries to other organs. This will help differentiate renal injuries that require operative management from those amenable to non operative strategies. CT abdomen with intravenous contrast is the recommended study for evaluating trauma patients with potential renal injuries. CT accurately shows renal cortical lacerations, contrast extravasation, peri-renal hematomas and vascular

injuries. A delayed scan after 10-20min is essential to evaluate the collecting system (17,18,19).

Findings on CT that suggest major injury include :

1. Decrease parenchymal enhancement early phase : Renal vascular injury
2. Medial hematoma : Renal vascular injury
3. Medial extravasation on delayed films : Renal pelvis or ureteric injury

Formal IVP has proven less effective than CT in staging renal trauma after blunt injury or stab wounds. IVP is not recommended for GSW (21).

Additionally IVP is time consuming, labour intensive and only visualises the urinary tract. The role of the intra-operative "single shot IVP" is limited to the haemodynamically unstable patient for immediate surgical intervention, to confirm a normal functioning contralateral kidney (20). It has no role in the staging of renal injuries. Ultrasound has gained popularity in the rapid diagnosis of intra-abdominal injuries in the trauma setting. Unfortunately it is operator dependent, and a large number of renal injuries are not diagnosed. MRI offers no benefit over CT in evaluation of renal trauma. It offers excellent detail of renal anatomy, but its ability to delineate urinary extravasation seems limited (22).

Management of Renal injuries:

Operative

The following are absolute indications for surgical exploration of renal injuries in trauma patients :

- Haemodynamically instability from a suspected renal injury.
- Renal hilum avulsion (Grade V).

- Renal pelvis or ureteric injury.
- Expanding or pulsatile retroperitoneal haematoma overlying the affected kidney (52).

If a stable retroperitoneal hematoma is found at laparotomy after penetrating trauma, in the *absence* of preoperative imaging, the kidney must be explored and repaired (23). Some authors have recommended that even patients who had preoperative imaging that confirms Grade III and IV injuries, who undergo explorative laparotomy for other reasons, should always have the kidney explored and repaired(24,45). *This may potentially lead to unnecessary nephrectomies being performed. In the setting of haemodynamic stability, adequate pre-operative imaging (ruling out a renal pelvis or ureteric injury), and an intra-operative non expanding retroperitoneal flank haematoma, the kidney most likely do not have to be explored and repaired.*

Relative indications for surgical exploration:

- Devitalised parenchyma > 20% (25).
- Persistent urinary leak, perinephric collections with failed percutaneous or endoscopic management.
- Failed angiographic embolisation.
- Renovascular hypertension.

Non-operative

In patients with blunt trauma, most injuries might initially be treated non-operatively. Even in the event of devitalised segments, these kidneys seem to heal well. In a series of over 2900 blunt renal injuries, only 2.6% of patients was managed operatively with a 0.7% nephrectomy rate (26). In most cases, urinary extravasation resolves without sequelae. If not, DJ stent

placement may be necessary for resolution of urine leak. Even bluntly injured Grade V shattered kidneys have been treated successfully without surgery. In a series of six shattered but perfused kidneys, four (66.6%) kidneys showed function before discharge as determined by CT (27). The conservative management of penetrating Grade V renal injuries is not recommended.

The non-operative management of penetrating renal injuries have remained a contentious issue. The successful non operative management of patients with stab wounds to the kidneys is well described (37,47). Armenekas et al, in a retrospective review over 20 years at San Francisco hospital of 200 stab wound kidneys, showed that 54% was managed non operatively. In this series however, 80% of renal injuries was Grade III or less (51). Heyns et al, showed that in 95 patients with stab wound kidneys, 63% were managed non-operatively. Delayed renal surgery had to be done on 4 patients(7%) with a delayed nephrectomy performed on 1 patient(3%) (37). However, evidence supporting non-operative care of *all* penetrating renal injuries has been more controversial. A landmark paper by Demetriades *et al*, reviewed 1856 patients with abdominal gunshot injuries. Of these an astounding 42% qualified for observation because of haemodynamic stability and an absence of peritoneal signs. Only 4% of these required interval delayed laparotomy for peritonism after a trial of non-operative management. This means 38% of patients never underwent laparotomy for their abdominal gunshot wound (44). There are authors that have successfully managed kidney gunshot injuries non operatively (46,48,49,28,51). Navsaria et al, from Groote Schuur Hospital, showed in a 4 year prospective study that 33 patients with renal gunshot wounds were selected (with strict criteria) for non-operative management. Only three patients required delayed laparotomy : 2 for non renal indications and one patient had a delayed nephrectomy. The overall successful NOM rate was 90.9%(46). McAninch et al, in a retrospective review over 14 years showed in 84 patients with renal gunshot wounds, that 21% can be treated non operatively (12). The rest of the literature supporting expectant care has been largely based on retrospective series of select patients (43).

In patients with penetrating injuries who are completely staged with imaging, select patients may be treated non-operatively. Limited renal injury are more suitable for this approach. Most Grade I&II renal injuries can be managed non-operatively with rare exception. Grade V injuries by definition represent a haemodynamically unstable situation requiring operative exploration. The non-operative management of Grade III and IV injuries has now been universally accepted. A large retrospective review by Wessels et al, have shown that Grade III and IV injuries that was treated non-operatively, had a high incidence (23.5%) of delayed renal bleeding (28). By doing initial surgical repair (renorrhaphy) of all renal injuries, this complication of delayed bleeding may be prevented. However, this delayed bleeding can be managed successfully with radiological embolisation without the need for renal exploration.

Renal injuries with nonviable segments may be managed non-operatively. There might however be increased morbidity (hospital stay, delayed surgical intervention) seen in these patients (67).

All patients who are managed non-operatively are placed on bed rest until macro-haematuria resolves. Repeat CT scans are reserved for patients with clinical manifestations of kidney-related complications, such as a significant drop in the haemoglobin level without hemodynamic compromise, pyrexia with elevated white blood cell counts, and/or worsening flank pain. Persistent or enlarging symptomatic urinomas on imaging are treated with percutaneous drainage or undergo a retrograde pyelogram and internally drained with a DJ stent. Patients with persistent macroscopic haematuria (>72 hours) may undergo renal angiography and embolisation.

Angio-embolisation

The role of angio-embolisation for delayed bleeding after non-operative management of penetrating renal trauma is well documented. As experience with NOM of renal trauma accumulates, the indications for selective embolisation may expand. Primary angio-embolisation has been advocated for renal stab wounds in one series, followed with surgical intervention if it fails (56). The concern with angio-embolisation is that functional parenchyma may be lost. With the advent of super selective embolisation techniques, the parenchyma loss might still be less than with open surgical repair (50). Success rates of 70-80% have been quoted for single renal artery branch injuries. Post embolisation syndrome is seen in 10% of patients (47).

Operative technique:

Proximal vascular control

The literature shows disagreement about the need for proximal vascular control. Some surgeons have suggested that pedicle control can be safely obtained following opening of Gerota's fascia. However, reports have shown their nephrectomy rates to be up to three times higher than those who do early vascular control (29,30). After exposing the root of the mesentery, a retroperitoneal incision is made over the aorta superior to the inferior mesenteric artery, and extending up to the ligament of Treitz. This gives excellent exposure to the renal vessels. Only after control of the renal pedicle, is Gerota's fascia then opened.

Renal reconstruction (renorrhaphy)

Renorrhaphy is the most common reconstructive technique. In the hemodynamically stable patient, it should at least be attempted prior to any nephrectomy. Partial nephrectomy is required when non-viable tissue is encountered. Renorrhaphy rates of 80.4% for stab wounds (51) and 66.6% for gunshot wounds (55) are reported in the literature.

The general steps of reconstruction are:

1. Measures for temporary vascular control
2. Entire kidney broadly exposed
3. Nonviable parenchyma debrided (>30% viable tissue left)
4. Haemostasis obtained (sutures, haemostatic agents)
5. Watertight closure of the collecting system
6. Re-approximate parenchymal edges
7. Omentum interposition flap to separate kidney from surrounding organs, especially if associated pancreatic or duodenal injury
8. Drain the area

Vascular injuries

Renovascular injuries are uncommon. In a survey over a 1 year period at 6 major trauma centres, only 89 patients had renovascular injury (31). Most injuries involved the renal artery only (60%), followed by renal vein (30%), followed by a combination of arterial and venous(10%) injury (32). Major renal vascular injury invariably requires operative management. They are frequently impossible to repair, and most likely leads to nephrectomy. Early proximal control is imperative if a repair is attempted (29). In specialist centres, renal salvage after major renal vascular injuries only occurs in 25-

35% (31). Time to perfusion is the major factor in determining outcome. Renal function is significantly impaired after 3 hrs of total and 6 hrs of partial ischemia. Despite technically successful repair, late hypertension occurs in up to 57% that were revascularised (33). Renal vascular repairs should be reserved for solitary kidneys, bilaterally injured kidneys, and rare situation of detection within 6 hrs of injury. Endovascular stenting has a limited role, as it requires anticoagulation, which is rarely possible in the traumatically injured patient.

Complications of renal injuries:

Extravasation of urine / Urinoma

The most common complication of renal trauma, as it is present in all patients with Grade IV parenchymal injuries or worse. It may also occur from renal pelvis or ureteric injuries. The prevalence is higher after penetrating trauma(10-30%), than after blunt trauma(2-18%). Only 13-26% of extravasation last longer than a few days of expectant management. In the rare instance of persistent extravasation, enlarging urinoma or development of fever/sepsis, the placement of a ureteric stent is indicated. In cases of renal pelvis or ureteric injury, open surgical repair is indicated (34).

Perinephric abscess

Perinephric abscess is rare, as it occurs in only 1% of all renal trauma and 5% of penetrating trauma cases. The main predisposing factors are devitalised renal segments, co-existing bowel/pancreas injury and immuno-compromised patients (35). Treatment consists of percutaneous drain placement with appropriate antibiotics. High mortality rates(12-57%) have

been reported with delay in treatment, but is uncommon with early diagnosis (36).

Secondary Haemorrhage

Secondary haemorrhage is one of the most serious complications of renal trauma. The prevalence is 13-25% after Grade III,IV blunt renal trauma and in 18-23% of all penetrating renal trauma who are treated conservatively. Research shows a lower secondary haemorrhage rate (3-15%) in patients following primary surgical exploration and repair (31,37). Most cases of delayed bleeding are caused by a traumatic pseudo-aneurysm or arteriovenous fistula(AVF). Bleeding is usually into the collecting system or into the peri-renal space and might be life threatening. Angiography with embolisation is the gold standard for evaluation and management for a suspected AVF/pseudo-aneurysm. Surgical gelatine, steel coils or autologous clot can be used to occlude the bleeding vessel. Absorbable material may cause lysis and lead to re-bleeding (50).

Hypertension

Hypertension may occur in up to 5% of renal trauma patients, although reports range widely(38). Long-term follow-up of trauma patients seems universally unreliable.

The main causes of hypertension are :

- Renal artery stenosis/occlusion (Goldblatt Kidney)
- Increased pressure on kidney from surrounding hematoma/scar (Page Kidney)
- Traumatic AV fistula

All three mechanisms leads to reduction in renal blood flow, that stimulates renin production. Spontaneous resolution of hypertension have been reported, therefore always start with conservative management. Oral anti-hypertensives controls the hypertension in 28-40% of patients (39). Surgery (renal revascularisation, capsulectomy, partial/total nephrectomy) is the next step in management.

Unnecessary nephrectomy

Although not a true complication, this is an avoidable procedure. Since conservative management for blunt renal trauma was introduced, 17-30% of kidneys have been “spared” (40). The literature reports nephrectomy rates of 11 – 47% across the board for all penetrating renal trauma (57,60,65,72). Unnecessary surgical exploration, inexperienced surgeons and failure to achieve early vascular control play a large role in unnecessary nephrectomies being performed.

Miscellaneous

- Post renal injury hydronephrosis
- Chronic flank pain
- Renal atrophy
- Renocutaneous fistula
- Chronic renal failure

Paediatric renal injuries

The kidney is injured in 10-20% of all blunt abdominal trauma in children. The lack of peri-renal fat, relative large size of the kidney and less protection from thoracic cage might explain why children are more susceptible to renal injuries. Blunt injuries account for >90% of renal injuries in children (73). Indications for imaging of children with suspected renal injury remains controversial. Morey et al, proposes that haemodynamically stable children with significant microscopic haematuria (>50RBC/HPF) after blunt renal trauma should get a CT abdomen (53). They feel that it is unlikely that any significant renal injuries will be missed with lesser form of microscopic haematuria. However, Stein et al proposes that all children with any of degree microscopic haematuria should be evaluated with CT abdomen after blunt renal trauma (62). This is the protocol we follow at Red Cross Children's Hospital. It is important to note that hypotension is a late presentation of hypovolemia in children. Blood pressure is therefore not a reliable criterion for imaging. There should be a low threshold for imaging after any penetrating injuries to the chest and abdomen. Selective non-operative management of renal injuries in children has the same principles as in adults. This conservative approach has led to a renal exploration rate of only 5-11% with renal salvage rate of >98% (74).

Chapter 2 : Introduction and aim of study

The conservative management of blunt renal trauma is well accepted. However, the role of non-operative management (NOM) of penetrating renal trauma remains controversial. At our trauma centre, patients selected for non-operative management (NOM) of penetrating renal injuries are staged with imaging, and if no indication for emergency laparotomy exists, these patients are then observed. The aim of this study is to prospectively review the management and outcomes of all penetrating renal injuries at a tertiary institution.

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Chapter 3 :Patients and methods

Institutional review board approval was obtained for the audit of a prospectively collected database of all penetrating renal injuries presenting to the Trauma Centre of Groote Schuur Hospital in Cape Town, South Africa over a consecutive 19-month period.

All patients presenting with penetrating abdominal injuries are initially assessed and resuscitated along Advanced Trauma Life Support (ATLS®) guidelines. Indications for emergency laparotomy are peritonitis (diffuse tenderness, rebound tenderness, guarding or rigidity), haemodynamic instability, blood per rectum and abdominal Injuries with associated head and spinal cord injuries that precluded serial abdominal examination. If haemodynamically stable these patients underwent a single shot intravenous pyelogram prior to laparotomy. Contrast material is injected intravenously and abdominal imaging is obtained after 10 minutes to assess the function of both kidneys. "Damage control laparotomies" is often necessary in the setting of the haemodynamically unstable, hypothermic and coagulopathic patient post penetrating abdominal injuries. In these situations, a nephrectomy often needs to be done to control haemorrhage, and complex renorrhaphy is not possible.

Haemodynamically stable patients presenting with haematuria, with no signs of peritonitis and an intact sensorium were candidates for a trial of NOM. These patients receive a CT scan of the abdomen with intravenous contrast to identify and stage the renal injuries. After the initial vascular phase a 10 minute delayed phase is done to evaluate the integrity of the collecting system. Injuries are graded using the American Association for Surgery of Trauma score (AAST) as summarized in Table 1.

Grade	Type	Description
1	Contusion	Haematuria, investigations normal
	Haematoma	Sub capsular, not expanding
2	Haematoma	Nonexpanding perinephric haematomas confined to the retroperitoneum
	Laceration	Superficial cortical lacerations less than 1 cm in depth without collecting system injury
3	Laceration	Renal lacerations greater than 1 cm in depth that do not involve the collecting system
4	Laceration	Renal lacerations extending through the kidney into the collecting system
	Vascular	Injuries involving the main renal artery or vein with contained haemorrhage
5	Laceration	Shattered kidney
	Vascular	Avulsed renal hilum devascularised kidney

Table 1: The AAST organ injury severity scale

Grade V penetrating renal injuries and renal pelvis/ureteric injuries excludes patients from NOM. Patients with confirmed kidney injuries (grades I–IV) are admitted to a high-care observation area for continuous hemodynamic monitoring, 4-hourly haemoglobin estimation, and serial clinical examination.

After 48 h in the high-care unit, once stabilised and tolerating food patients are transferred to a general trauma surgical ward. In the event of the development of peritonitis or hemodynamic instability at any time, laparotomy is performed.

Conservatively managed patients are treated with bed rest until any macroscopic haematuria had resolved. Repeat CT scans are reserved for patients with clinical manifestations of kidney-related complications, such as a significant drop in the haemoglobin level without hemodynamic compromise, pyrexia with elevated white blood cell counts, and/or worsening flank pain. Persistent or enlarging symptomatic urinomas on imaging are treated with percutaneous drainage or undergo a retrograde pyelogram and internally drained with a DJ stent. Patients with persistent macroscopic haematuria (>72 hours) undergo renal angiography and embolisation.

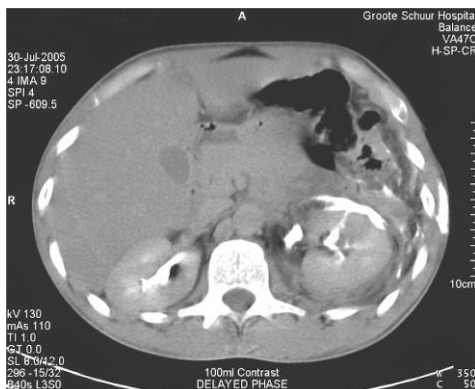
During this audit the following aspects was analysed: mechanism of injury, presence of microscopic/macroscopic haematuria, investigations done (CT scan or IVP), grade of renal injury (AAST), management decision (non-operative without laparotomy, operative with laparotomy but Gerota's fascia not opened, operative renal exploration), non-operative success, non-operative complications, hospital stay, transfusion requirements as well as nephrectomy rate in patients explored.

Chapter 4 : Results

A total of 92 patients with penetrating abdominal injuries presented with microscopic or macroscopic haematuria. 70 patients (75 kidneys) had confirmed renal injury. 5 patients had bilateral renal injuries. These injuries were diagnosed with imaging or intra-operatively if the patient received an emergency laparotomy. A Total of 60 CT scans (65.2%) of the abdomen, 5 formal IVP's(5.4%) and 18 documented single shot IVP's (19.6%) were performed. Nine patients (9.8%) were directly brought to the operating room without any documented further imaging.

The median age of all the patients was 26 years(range 14 -51). There were 84 males (91.3%) and 8 females (8.7%). The mechanism of injury was 50 stab wounds (54.3%) and 42 low velocity gunshot wounds (45.7%).

In this study all patients presented with either microscopic (65.2%) or macroscopic (34.8%) haematuria. The presence of microscopic or macroscopic haematuria was compared to the grade of renal injury (AAST) (Table2). There were 22 patients with haematuria (21 microscopic and 1 macroscopic) that had no definable renal injury on imaging. Microscopic haematuria diagnosed in 39 cases was associated with grade I, II, III, IV and V renal trauma in 5 (12.8%), 16 (41.0%), 12 (30.8%), 5 (12.8%) and 1(2.6%) patients, respectively. The table demonstrates that 18 patients (46.2%), with microscopic haematuria and confirmed renal injury, had a grade III injury or worse. Also, 29 patients(93.5%), that presenting with macroscopic haematuria and confirmed renal injury, had Grade III injury or worse ($p<0.001$).



Picture 1 : Grade IV renal injury

	Microscopic haematuria	Macroscopic haematuria
<i>No injury</i>	21	1
Grade 1	5	1
Grade 2	16	1
Grade 3	12	11
Grade 4	5	12
Grade 5	1	6
Total	60(65.2%)	32(34.8%)

Table 2: Haematuria and its distribution with grade of injury.

There were 36 patients (51.4%), from the 70 patients with confirmed renal injuries, that had associated intra abdominal injuries. The mechanism of injury with associated intra abdominal injuries was 26 GSW (72.2%) and 10 stabs (27.8%). Liver (29.3%) and colon (20.7%) injuries were the most common associated intra abdominal injuries. Gunshot injuries were significantly more associated with liver (82.4%) and colon (83.3%) injuries as compared to stab wounds ($p < 0.001$). Renal injuries with associated intra-abdominal injuries are summarised in Table 3.

Associated abdominal injuries	Total	Gunshot wounds	Stab wounds
Liver	17 (29.3%)	14 (82.4%)	3 (17.6%)
Colon	12 (20.7%)	10 (83.3%)	2 (16.7%)
Stomach	7 (12.1%)	7 (100%)	0 (0%)
Spleen	6 (10.3%)	3 (50%)	3 (50%)
Small bowel	9 (15.5%)	6 (66.7%)	3 (33.3%)
Diaphragm	2 (3.4%)	1 (50%)	1 (50%)
Pancreas	2 (3.4%)	2 (100%)	0 (0%)
Duodenum	2 (3.4%)	1 (50%)	1 (50%)
Appendix	1 (1.7%)	1 (100%)	0 (0%)

Table 3: Associated intra-abdominal injuries.

A total of 47 patients with 49 penetrating renal injuries (65.3%) the renal injuries were treated non-operatively. No laparotomy was performed in 34 of these patients, while in 15 patients (who had a laparotomy for another indication) the Gerota's fascia was not opened. In this non-operative group the renal injuries were graded I, II, III, IV, and V in 6 (12.2%), 17 (34.7%), 17 (34.7%), 9 (18.4%), and 0 (0%) cases, respectively. Associated intra-abdominal injuries was found in 20 patients (42.6%), in this group where the renal injuries were treated non-operatively. These non-operative managed patients were also stratified separately into gunshot wounds and stab wounds (Table 4). There was no conversion to surgical exploration in any patients initially selected for NOM (100% success rate).

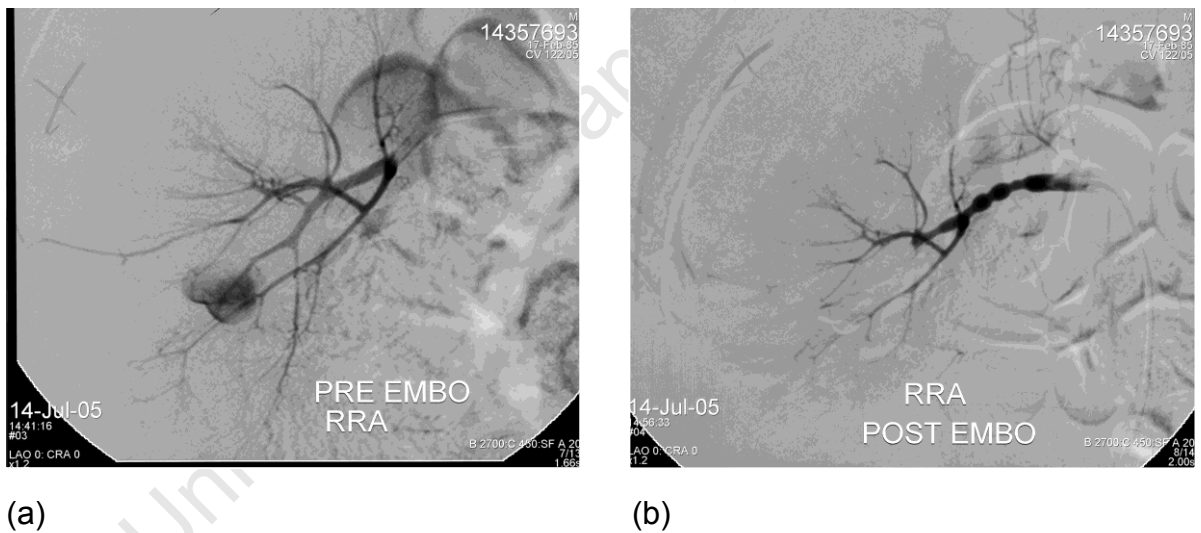
		Gunshot wounds	Stab wounds
All renal injuries(%)	75 (100%)	36 (48.0%)	39 (52.0%)
Non-op mx	49 (65.3%)	19 (39.8%)	30 (61.2%)
Grade I	6(12.2%)	2(10.5%)	4(13.3%)
Grade II	17(34.7%)	9(47.3%)	8(26.6%)
Grade III	17(34.7%)	6(31.6%)	11(36.7%)
Grade IV	9(18.4%)	2(10.5%)	7(23.3%)
Grade V	0(0%)	0(0%)	0(0%)

Table 4: Non operative management of penetrating renal injuries.

There were 4 patients (8.2%)(0.02-16.1)% who presented with delayed macroscopic haematuria as complication after non-operative management (Table 5). All of these were after stab wound injuries. Angiogram revealed 1 false aneurysm and 2 arteriovenous fistulae that were successfully embolised. No abnormality was found on the angiogram of the fourth patient, in whom the haematuria settled after 48 hrs of observation. These were the only complications noted at a minimum of 6 months follow-up post injury. There were no complications in the NOM of gunshot renal injuries. The median blood transfusion rate in the NOM patients was 0, (range 0-7). The median hospital stay for patients undergoing successful NOM of renal injuries was 6 days, range (1-32).

	Complication	Injury	Grade	Angiogram	Management
Patient 1	Macroscopic haematuria	Stab	III	False aneurysm	Embolised
Patient 2	Macroscopic haematuria	Stab	III	AV Fistula	Embolised
Patient 3	Macroscopic haematuria	Stab	III	Normal study	Conservative
Patient 4	Macroscopic haematuria	Stab	IV	AV Fistula	Embolised

Table 5 : Complications of non-operative management



Picture 2 : Renal false aneurysm post stab wound. (a) Pre embolisation
(b) Post embolisation

Surgical renal exploration was performed as initial management in 25 patients with 25 penetrating renal injuries (33.3%). The mechanism of injury in this group was 16 GSW(64%) and 9 SW(36%). In this operative group the renal

injuries were graded I, II, III, IV, and V in 0(0%), 0(0%), 9 (36%), 9 (36%), and 7 (28%) cases, respectively(Table 6).

		Gunshot wounds	Stab wounds
All renal injuries(%)	75 (100%)	36(48.0%)	39(52.0%)
Operative management	25 (33.3%)	16 (60.0%)	9 (40.0%)
Grade I	0 (0%)	0 (0%)	0 (0%)
Grade II	0 (0%)	0 (0%)	0 (0%)
Grade III	9 (36.0%)	4 (25.0%)	5 (55.6%)
Grade IV	9 (36.0%)	6 (37.5%)	3 (33.3%)
Grade V	7 (28.0%)	6 (37.5%)	1 (11.1%)

Table 6 : Operative management of penetrating renal injuries

A total of 9/25 renorrhaphies (36%)(15.8-56.2) were performed (7 renal cortical repairs and 2 renal pelvis repair). Intra operatively 2/9 renorrhaphies failed(22.2%) that led to nephrectomies being performed. There was one complication post renorrhaphy(11.1%), a perinephric collection after renal pelvis repair was diagnosed with ultrasound. This was treated successfully with percutaneous drainage. The median hospital stay for patients who had surgical renal exploration was 8 days (range 1-34). The median blood transfusion rate was 2 units(range 0-9).

18 Nephrectomies were performed for 75 penetrating renal injuries, with an overall nephrectomy rate of 24%(14.1-33.9)%. In the 25 patients that was surgically explored, the nephrectomy conversion rate was 72%(53.1-90.9)%. The mechanism of injury was 5 SW(27.8%) and 13 GSW(72.2%). In 14 of the 18 patients (77.8%) there were other associated intra abdominal injuries. The reason for nephrectomy (surgeon's operative notes) was as follows: major

haemorrhage 11 (61.1%), shattered kidney 3 (16.7%), hilar injury 2(11.1%) and no reason stated 2 (11.1%). In this nephrectomy group the renal injuries were graded I, II, III, IV, and V in 0(0%), 0(0%), 3(17%), 8(44%), and 7 (39%) cases, respectively(Table 7).

		Gunshot wounds	Stab wounds
Nephrectomy	18 (24.0%)	13 (72.0%)	5 (28.0%)
Grade I	0 (0%)	0 (0%)	0 (0%)
Grade II	0 (0%)	0 (0%)	0 (0%)
Grade III	3 (16.7%)	1 (7.6%)	2 (40.0%)
Grade IV	8 (44.4%)	6 (46.2%)	2 (40.0%)
Grade V	7 (38.9%)	6 (46.2%)	1 (20.0%)

Table 7 : Nephrectomies in penetrating renal injuries

The median blood transfusion rate in all patients that had a nephrectomy was 2 units, range (0–9). The median hospital stay was 8 days, range(1-34).

Comparing hospital stay and transfusion requirements between the non operative managed patients and operative managed patients, it showed that hospital stay (p 0.009) and transfusion requirements (p 0.003) differed significantly according to the non operative status (Wilcoxon rank sum test).

There was a total of 4 “damage control laparotomies” performed in the 25 patients surgically explored. There were 2 patients that needed a nephrectomy as part of this procedure. There was 1 death after a “damage control lapatotomy”. The only morbidity seen after a nephrectomy, was a patient that had an infected renal bed haematoma. This was successfully drained percutaneously.

Chapter 5 : Discussion

South Africa has a huge burden of morbidity and mortality from violence and traumatic injury. In 2000 the country recorded 60 000 deaths due to injury, with a death rate of 160 per 100 000 population. This figure is higher than for the rest of Africa and is nearly twice the global average. It is shown that 50% of these deaths are due to injury caused by interpersonal violence. This is 5 times higher than the rest of the world (41). The commonest cause of unnatural death in South Africa is homicide, accounting for 45% of all fatal injuries. On an average day, 51 people in South Africa are murdered in a country of 47 million (42). South Africans are estimated to be 12 times more likely to be murdered than an average Westerner. Gunshots contribute 29% and stabs 15% to these fatalities (42). Against this background it is not surprising that South Africa has produced many of the largest published trauma series.

In the past few decades the management of traumatic renal injuries has undergone a revolution from mandatory surgical exploration to non-operative care. These protocol changes have resulted from improved trauma care, better imaging and the evidenced based success of conservative approaches.

In all genitourinary trauma cases, more than 50% involve injury to the kidney. Renal injuries are theoretically more amenable to non operative management than other intra-abdominal solid organ injuries. The retroperitoneal position of the kidneys may contain hemorrhage, and the rich blood supply may promote healing, even after severe parenchymal injuries.

Expectant non-operative management of blunt renal trauma has gained much support in past decades (66,67,68,71). The expectant management of penetrating renal injury has still not been universally accepted. The successful non-operative management of patients with stab wounds to the kidneys is well described (9,69). However, evidence supporting non-operative care of all penetrating renal injuries (ie. stabwounds, missiles) has been more controversial, and hence we set out to prospectively document

our experience. The literature supporting expectant care has been largely based on retrospective series of carefully selected patients (43). One important series, however, indicates that modern approaches to penetrating abdominal injuries are certainly changing. In this study, Demetriades *et al*, reviewed 1856 patients with abdominal gunshot injuries. Of these an astounding 42% qualified for observation because of haemodynamic stability and an absence of peritoneal signs. Only 4% of these required interval delayed laparotomy for peritonism after a trial of non-operative management. This means 38% of patients never underwent laparotomy for their abdominal gunshot wound (44). There are other authors that have successfully managed kidney gunshot injuries non operatively (46,48,49,28,51). This shows that opinions advocating aggressive surgical management of penetrating abdominal injuries to all intra-abdominal solid organs are softening. Prompt surgical intervention is still reserved for haemodynamically instability due to renal haemorrhage, renal pelvis or ureteric injury, Grade V injuries or intra-operative finding of a pulsatile/expanding peri-renal haematoma. Conservative management implies regular monitoring of vital signs, abdominal symptoms and signs and haemoglobin. Bed rest is maintained until clinical signs have been stable for a few days and macroscopic haematuria has cleared. Strenuous physical exertion should be avoided for 6 weeks (52).

Our series supports the role for non-operative management (NOM) in cases of penetrating renal injuries. Of the 92 patients with penetrating abdominal trauma and haematuria, there were 75 proven renal injuries. We successfully managed 65.3% of the latter non-operatively. Outcomes of NOM were excellent with no conversion to surgical exploration in patients initially selected for NOM.

Four patients (9%) developed delayed haematuria(1 false aneurysm, 2 AVF and 1 patient had a normal angiogram) after NOM. 3 of 4 patients was successfully treated with angio-embolisation. No patients had to receive delayed open renal surgery after initial non-operative management. The literature reports the incidence of delayed bleeding in patients treated conservatively being up to 23.5% (28,69,70). Greater transfusion

requirements and haemodynamically instability are also reported in this population (28).

Table 8 summarises the largest studies that reviewed the non operative management of penetrating renal injuries (Gunshot wounds, Stab wounds).

a) Gunshot wounds

	Patients	Managed non-operatively	Delayed renal surgery	Delayed Nephrectomy
Navsaria(46)	95	33(35%)	1(3%)	1(3%)
McAninch(12)	84	15(21%)	0	0
Velmahos(57)	52	20(38%)	1(5%)	0
Thall(68)	16	5(31%)	1(20)	0

b) Stab wounds

	Patients	Managed non-operatively	Delayed renal surgery	Delayed Nephrectomy
Armenekas(51)	200	108(54%)	3(3%)	0
Heyns(37)	95	(63%)	(7%)	(3%)
Wessels(28)	71	36(51%)	3(4%)	0
Thall(68)	16	11(69%)	0	0

Table 8 : Penetrating injuries stratified into a) gunshot wounds and b) stab wounds

In our study all 92 patients presented with microscopic or macroscopic haematuria. The literature reports that up to 5% of patients with penetrating renal injuries might present with no haematuria (60). We had 21 patients(18.5%) with microscopic haematuria that had no detectable renal injury. There were however 18 patients(46.2%), with microscopic haematuria and confirmed renal injury, that had a significant renal injury(Grade ≥ 3). This clearly shows that microscopic haematuria has no association with the degree of renal injury. Also, most patients [29 patients(93.5%)] with macroscopic haematuria had significant renal injury(Grade ≥ 3)(p <0.001).

Abdominal computerized tomography (CT) is the most sensitive imaging method and remains the cornerstone for the diagnosis and classification of renal injury (54). CT accurately identifies vascular injury, parenchymal laceration, urine extravasation and peri-renal haematoma. IVP might also be

performed as imaging method in the evaluation of haemodynamically stable patients with renal injury. In patients with renal proximity stab wounds IVP is 96% accurate in establishing the presence or absence of renal injury(56). However, IVP is not recommended for GSW(21). Additionally IVP is time consuming, labour intensive and only visualises the urinar tract. One shot IVP was once advised , but is less sensitive in detecting renal injuries. In the haemodynamically unstable patient it has a role to confirm the existence of a contralateral functioning kidney (58).

Of the 70 patients with 75 proven renal injury we had a high nephrectomy rate of 24.3%. The literature reports nephrectomy rates of 11 – 47% for all penetrating renal trauma (57,60,65,72). A recent review of 8465 blunt and penetrating renal trauma patients showed an overall nephrectomy rate of 7.3%(59). High nephrectomy rates needs to be understood in the context of an unstable patient with multiple injuries where time-consuming renal salvage procedures are clearly contraindicated and who often require “damage-control” laparotomy (46). Also, patients who are likely to require nephrectomy are those who sustained a gunshot injury, have greater severity of injury, a high renal injury grade, haemodynamically instability and those who require ongoing blood transfusion (60). For patients who require renal exploration, data suggests that nephrectomy rates can be decrease by using early vascular control, which alone decreased nephrectomy rate from 56% to 18% in one important series (60). If there is a renal injury with haematoma overlying the renal vessels, medial exploration with early vascular control should be considered before opening the Gerota’s fascia (61).

A total of 9 renorrhaphies (36%) were performed in our series. Other authors describe renorrhaphy rates of 80.4% for stab wounds (51) and 66.6% for gunshot wounds (12). However, a high percentage of kidneys(79.3%) was explored in the renorrhaphy for the gunshot wound series(12). Therefore a large number of these renal reconstructions might have been made on lower grade renal injuries. Still, more renorrhaphies should be attempted at our institution.

In our study, of the 25 kidneys that was surgically explored, lead to 18 nephrectomies (72%) being performed. This confirms that patients where

renal injuries were surgically explored, had a significant risk of having a nephrectomy performed. There is the concern that routine renal exploration of all injured kidneys will result in increase rate of nephrectomy(57,63,64). It is my feeling that with adequate preoperative imaging, in a haemodynamically stable patient without intra-operative expanding/pulsatile haematoma, the kidney does not have to be explored. Routine exploration of the injured kidney may result in the unnecessary loss of the kidney. The loss of a kidney, especially in the presence of other major associated injuries or septic complications, may also increase overall morbidity. The goal of non-operative management is to minimize incidence of negative explorations and unnecessary repairs which lead to unnecessary nephrectomies, without increasing morbidity and mortality.

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Conclusion :

Penetrating abdominal trauma and concomitant haematuria is associated with a high rate of renal injury (80.4%). Patients that present with microscopic haematuria the incidence of higher grade renal trauma (\geq III) is up to 46.2%. This clearly shows that microscopic haematuria has no association with the degree of renal injury. In our series, we had a overall nephrectomy rate of 24%. If the decision for renal exploration is made, the nephrectomy conversion rate is as high as 72%. Conservative management leads to a high organ preserving success rate (100%) with minimal morbidity (8.2%). Also, hospital stay(p 0.009) and transfusion requirements(p 0.003) were shown to be significantly lower in the non operatively managed patients. This information is crucial for clinical decision making, as aggressive surgical management with renal exploration leads to high rate of potentially preventable nephrectomies.

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APPENDIX

The Protocol : Application to Ethics committee to conduct medical research

Surgical protocol approval for journal article publication

Title of study:

Non-operative vs. operative management of penetrating kidney injuries

Investigators:

Dr C Moolman MBChB FC Urol (SA)
Prof PH Navsaria

Introduction:

The conservative management of blunt renal trauma is well accepted. To date there is little data on conservative management of penetrating renal trauma. The aim of this study was to review the management and outcome of a large patient cohort presenting with penetrating renal trauma to a tertiary referral centre in South Africa.

Study design :

Retrospective audit of a prospectively collected database of all penetrating renal injuries over a 19 month period.

Objective :

Review of the management and outcome of all penetrating renal injuries (gunshot wounds and stab wounds). The following patients data was collected: demographics, mechanism of injury, micro vs macrohaematuria, grade of injury(AAST),management decision(non surgical, surgical for other reasons without renal exploration and true renal surgery with Gerota's fascia opened), non-surgical success rate, complications, hospital stay and nephrectomy rate.

Background :

In the past few decades the management of traumatic renal injuries has undergone a revolution from mandatory surgical exploration to non-operative

care. These protocol changes have resulted from improved trauma care, better imaging and the evidenced based success of conservative approaches. (1) In all genitourinary trauma cases, more than 50% involve injury to the kidney. Renal injuries are theoretically more amenable to non-operative management than other intra-abdominal solid organ injuries. The retroperitoneal position of the kidneys may contain bleeding, and the rich blood supply may promote healing even after severe parenchymal injuries. (2) Expectant (non-operative) management of blunt renal trauma has gained much support in past decades. (3) The expectant management of penetrating renal injury has still not been universally accepted. Successful non-operative management of patients with stab wounds to the kidneys were published as far back as 1985. (4) However, evidence supporting non-operative care of penetrating renal injuries has been more controversial and hence we set out to prospectively document our experience.

Clinical importance of study:

This information on outcome of non operative managed renal injuries is crucial for clinical decision making, as aggressive surgical management with renal exploration potentially leads to high rate of preventable nephrectomies.

Objectives:

- 1) Review outcome of non-operatively managed renal injuries
- 2) Review our nephrectomy rates
- 3) Compare our results with those in the literature
- 4) Add to the body of literature to assist in clinical decision making

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