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Long-term functional follow-up after kidney injury in children:

Retrospective review of 33 cases

Etudiant
Roschan Hayoz

Tuteur
Dr. Nicolas Lutz

Dpt de chirurgie pédiatrique, HEL

Co-tuteurs
Dr. P. Frey, B.J. Meyrat, G. Dushi
Dpt de chirurgie pédiatrique, HEL

Experte
Dre. Ariane Boubaker

Dpt de médecine nucléaire, CHUV

Statisticien

P. Ballabeni

Centre de recherche clinique,

Institut universitaire de medicine sociale et preventive (IUMSP),

(CHUV)

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Abstract

Introduction

Renal injuries accounts for 8-12% of all pediatric abdominal trauma, of which >90% are blunt and treated conservatively. Questions remain regarding the most adequate follow-up and whether there is a correlation between grade of injury and long-term renal function.

The purposes of this study were to assess the treatment of renal injuries in our institution, evaluate the complications and analyse late functional outcome.

Method

Retrospective review of renal injuries over 22 years in one institution. Patient's demographics, mechanism and grade of injury, associated injuries, management and complications were collected. Consecutive follow-up 123-I-hippuran dynamic renographies (RG) were reviewed and statistical analysis of renal function evolution was assessed.

Results

33 children were identified, consisting of 22 males and 11 females. The mean age was 11.5 years (median 10.6; range 1.5-15.8). All injuries were blunt. There were 2 (6%) grade I, 3 (9%) grade II, 11 (33%) grade III, 9 (27%) grade IV and 8 (25%) grade V. Associated injuries occurred in 24 children. Treatment was surgical in 8, minimal invasive in 15, and non-operative in 13. Complications included 3 urinary infections, 2 hydronephrosis, 14 urinomas, 1 pseudoaneurysm, 1 renal artery thrombosis, 2 calculus and 2 cysts. Chronic hypertension occurred in 3 and chronic renal insufficiency in 2children. Long-term follow-up of renal function consisted of 1 to 8 dynamic renographies (2.9±1.9) over a follow-up period of 1.8 to 16 years (4.6±3.9). Overall long-term function correlated with grade of injury and a trend towards functional loss was observed over time. Detailed renal function analysis will be presented

Conclusion

In our population, the proportion of grade III and above injuries was high when compared to the literature.
The majority of children were treated non-operatively or with minimal invasive procedures.
Late occurring clinically significant complications were numerous and warrant long-term clinical and functional follow-up in most cases.

Key words: kidney injury, pediatrics, long-term follow-up, I-123-OIH dynamic renography

Summary

1. Introduction

Renal trauma accounts for 8-12% of all abdominal trauma.(1) In children, more than 90% of renal injuries are secondary to blunt trauma. In children, abdominal muscles and peri-renal fat are less developed when compared to adults. The kidney is also of proportionally greater size when therefore less protected by the surrounding thoracic bone structures.(2)

Injected Computed Tomography (CT) imaging of the kidney is the gold standard radiological evaluation to determine the severity of trauma and to classify it according to the American Association for the Surgery of Trauma (AAST) grading criteria. The grading of injury, especially the extent of renal cortex laceration, vascular injury and rupture of the collecting system are essential information decision-making for further management (1)(3).

Over the past decades, there has been a change in attitude of pediatric injuries and a shift towards conservative treatment of parenchymal injuries. It is now widely accepted to treat pediatric renal parenchymal injuries conservatively (1)(4)(5)(6).
Concerns remain as to how long an injured kidney should be controlled and which functional evaluation is best to assess post-trauma function (7).

According to several large series, the functional outcome of children with nonoperatively managed kidney injuries was good and correlated with injury grade (8)(9)(10). In these studies, long-term follow-up was rarely conducted for more than one year (11)(8). El Sherbiny et al. reported a mean follow-up of 3 years and concluded that a prolonged follow-up was necessary.

Renal function is commonly assessed by radionuclide imaging using Tc-99m labeled dimercaptocuccinic acid (Tec-99m DMSA) for static cortical scintigraphy or Tc-99m mercaptoacetyltriglycine (Tc-99m MAG3) or orthoiodohippurate (I-123 OIH) dynamic renal scintigraphy(12). DMSA is taken up by tubular cells of the pars recta directly from the peritubular vessels and is scarcely excreted allowing precise and accurate delineation of the parenchyma and is scarcely excreted(13). The relative renal function has been standardized as normal to mildly impaired when the injured kidney achieved more than 40% differential renal function. Moderate impairment is considered when the injured kidney provides 30 to 40% differential function and severe impairment if the injured kidney contributed to less than 30% (4)(9). Dynamic tracers are extracted and secreted either as pure tubular tracers (Tc-99 MAG3) or mixed tracer like I-123-OIH with glomerular filtration rate of approximately 20% and tubular extraction rate of 80%. Both tracers allow more complete functional evaluation of the kidneys, from the parenchymal extraction to the urinary outflow (14). At the Lausanne University Hospital, all children with renal injuries were submitted to post-trauma serial I-123-OIH dynamic renography with determination of absolute and relative renal function. Individual kidney function is measured by an accumulation index (AI) expressed as percent of injected activity extracted by each kidney over 1 minute, 30 seconds after heart-peak(15). Relative function (RF) represents the contribution of each kidney in percent to the global function obtained by adding left and right AI. We hypothesized that post-trauma renal function can decrease over time and that it may not be related to the severity of trauma (grading).

The purposes of this study were to review pediatric kidney injuries with regards to grading, management, complications and more specifically functional outcome, using grading according to the AAST and functional assessment by serial I-123-OIH dynamic renography.

2. Method

Following approval from the Research Ethics Committee, a retrospective review of 33 consecutive patients presenting renal injuries over a 22-year period was performed. Patient's demographics including age at the time of injury, gender, mechanism and grade of injury, as well as associated injuries were recorded. The mechanism of injury was defined as sports-related, following a motor vehicle accident (MVA), a fall or an impact to the flank with an object or a limb (direct hit). The injury was diagnosed based on renal ultrasound and abdominal computed tomography (CT). The grade of injury was determined according to the grading criteria of the American Association for the Surgery of Trauma (AAST).(16)

The associated injuries were classified according to body regions, including thorax, abdomen, skeleton, head and skin.

The type of management was recorded. A non-operative approach was considered when the kidney was left alone and remained undrained and untouched. Renal percutaneous or trans-ureteral drainage was considered as a minimally invasive (MI) procedure. Percutaneous arterial embolization, balloon dilatation or stenting were also considered as MI. Open surgery to the kidney and pyelo-ureteral system were classified as surgical management.

Relative (RF) and absolute individual (AI) kidney function were measured during I-123-OIH dynamic renography for each injured and uninjured kidney (left or right) Excretion and urinary flow was measured by an elimination index (EI). All sequential parameters were collected and used for statistical analysis.
The statistical method applied for the analysis of renal function over time consisted of longitudinal analysis conducted by models with marginal coefficient (population-averaged model). These models take into account that two measures taken on the same item at different times are not independent of each other. Prior hypothesis is that renal function decreases as a function of time. Each renal function variable was modeled according to injury grade. Children were divided in two groups based on the severity of the renal injury: Grade I to III injuries were considered as one group and the more severe grade IV to V injuries in second group. Statistical analysis was performed in both groups.
Relative renal function (RF) of the affected and the non-affected kidney were recorded and evaluated as a function of time in both groups. Descriptive analysis of dynamic renographies was performed: mean relative renal function was determined for each grade. Three children with high injury grade were excluded: one child a single, two children had nephrectomy of the injured kidney. The mean relative renal function and the standard deviations were calculated for the injured and uninjured side for each grade at first renal functional assessment as well as at the latest assessment. Interval between the trauma and the first renography, follow-up period in years and the total number of renographies per child were recorded.

Post-trauma ambulatory blood pressures were recorded, when available.
Follow-up protocol included regular ultrasonography and/or Ct-scanning. In specific cases Doppler ultrasound, angiography or MRA were performed. Medical and surgical complications were classified into early (within one month) and late (after one month) complications.

3. Results

3.1 Demographics

A consecutive series of 33 patients with (22 male and 11 female) with blunt renal trauma was selected over a 22-year period from 1990 to 2012. Mean age was 11.5 ±10.6 years (range: 1.5 – 15 years).

Falls and sports activity were the most common cause of injury, in 12 (36%) and 11 (33%) children respectively. Six children (18%) have been involved in motor vehicle accidents (MVA). In 3 children (9%) renal trauma results from a direct hit to the kidney. (Figure 1)

MVA were the most common cause of grade V injuries, falls in most grade IV injuries. Sports were more frequently associated with grade III injuries. (Figure 2)

Congenital renal abnormalities were found in three children: uretero-pelvic junction stenosis with hydronephrosis in one grade I, a horseshoe kidney in one grade IV, unique congenital kidney in another grade IV.

This series included a majority of grade III or higher-grade injuries: 11 grade III, 9 grade IV and 8 grade V. Only a minority of children had low-grade injuries (5 of 33): 2 grades I and 3 grades II. Urine analysis were available in 28 children (85%): hematuria was found in 13 cases (39%) (1 gr I, 2 gr II, 3 gr III, 5 gr IV, 2 gr V). (Figure 3)

3.2 Associated injuries

Associated injuries were abdominal, thoracic, musculoskeletal, cranio-cerebral and in connection with dermis. Concomitant lesions were abdominal in most cases. Thoracic injuries were also common. Musculo-skeletal associated injuries occured mainly in high-grade V injuries (n=4). Cranio-cerebral injuries and dermabrasions are minor (n=7).

They were more frequently observed in children with high grade injuries (7gr III, 8 gr IV, 7 gr V). 9 children (27%) had isolated renal injury.

Figure 4 shows the distribution of associated injuries according to renal injury grade: most associated injuries occurred in grade III to V. In children with grade III kidney lesions a majority of non-renal abdominal concomitant lesions were diagnosed, as well as for children with grade V renal trauma. Thoracic injuries occurred more frequently in grades IV and V. Cranial trauma was seen once in grade I and twice in grades IV and V.

Figure 5 shows the distribution of associated injuries according to the management and grade of injury. Associated injuries were more common in high-grade renal injuries (grades IV and V). Management remained minimally invasive in most grade IV and V injuries despite concomitant lesions.

3.3 Management of renal trauma

Figure 6 shows the distribution of management (NO: non-operative, MI: minimally invasive, S: surgical) according to the grade of injury.

Surgical management consisted in nephrectomies (n=2), renorrhaphy (n=1), vascular repair (n=1), early (n=1) and late (n=3) pyeloplasty and partial nephrectomy (n=1). The majority of children were treated conservatively.

Figure 7 illustrates the distribution of the children treated by surgery according to the grade of injury.

Four children underwent immediate surgery: two children underwent surgical exploration for hemodynamic instability (one grade III, one grade V). The youngest child of our series who had a grade III renal trauma was submitted to renorrhaphy. One child with grade V underwent nephrectomy because of « shattered kidney ». Another child with grade V underwent laparotomy for nephrectomy because of thrombosis of renal artery. This child was hemodynamically stable at admission. Four children underwent pyeloplasty: grade I (n=1), grade III (n=1) and grade V (n=2). PUJ stenosis with hydronephrosis was diagnosed at the time of admission in the child with grade I kidney injury. The child with grade III underwent pyeloplasty as well as partial nephrectomy for late developing calculus and pyelic ectasia (7 years post renal trauma). Two grades V underwent pyeloplasty because of late developing PUJ stenosis after unsuccessful ureteral stenting.

Figure 8 shows the distribution of the children treated with minimal invasive techniques.
14 children received immediate ureteral stenting because of urinoma (3 gr III; 7 gr IV; 4 gr V). This was changed for percutaneous drainage in 3 children because initial ureteral stenting was not efficient (one grade IV, 2 grade V): these children developed significant stenosis of the pyelo-ureteral junction. Both grades V required late pyeloplasty. Grade IV had another ureteral stenting.
Three children underwent interventional radiology procedures for delayed bleeding (one gr IV and 2 gr V). Grade IV was treated by supraselective embolization of a pseudoaneurysm. In one grade V angiography showed dissection of a renal artery that was managed by arterial balloon dilatation. Another grade V with dissected renal and peri-hilar renal artery underwent arterial stenting.

Figure 9 shows the distribution of the 13 children managed non-operatively where grades I to III were more frequently observed. 9 children (69%) had associated injuries. Complications occurred in 5 children (38%): transitory hypertension (n=2), infectious (n=1), renal cysts and late hypertension (n=1) and transitory hypertension and blood loss (n=1).

3.4 Complications

Complications occurred in one grade I, 5 grade III (45%), 8 grade IV (66.7%) and all grade V injuries (100%). Figure 10 shows the distribution of complications according to management and grade of kidney injury.
Renal pelvis ectasia persisted over time in one child with grade I submitted to pyeloplasty for early PUJ stenosis diagnosed at the time of injury. No complications were observed in grade II kidney injuries.
In grade III transitory hypertension was recorded (n=1), fever (n=1). Two children had several complications: early blood loss, early hypertension and late renal cysts in one; another with blood loss, calculus, hydronephrosis that resolved spontaneously and hypertension controlled by medication. All four had non-operative management. The fifth child underwent late surgery for calculus and concomitant pyelic ectasia.
In grade IV, seven children developed urinoma, which was managed later by ureteral stenting. In one child management was non-operative although transfusion was required for severe blood loss. Hypertension was also recorded in this child during the hospital stay. In grade V, one child with primary nephrectomy developed late pyelic ectasia.
Another child with several complications (important blood loss at admission, fever and bridled ileus after surgery developed late renal insufficiency.
Two children developed PUJ stenosis after ureteral stenting for which both underwent late pyeloplasty. Five children received minimally invasive treatment: ureteral stenting efficient in 2. Immediate percutaneous arterial stenting (n=1) and arterial balloon dilatation (n=1) were performed. Hypertension developed in the child with arterial stenting 4 years trauma. The other child had no complications.

Figure 11 shows the distribution and number of early complications among grades III to V.
Fever was recorded after surgery and during the hospital stay in 9 children (27.3%) (4 gr III, 3 gr IV, 2 gr V). Fever was most frequent in grade III.
Urinary infection and pyelonephritis were rare, occurring in one grade III and one grade V.
Urinary leackage and blood loss were the most frequent early complications. Hypertension occurred in 3 children. Vascular complication occurred twice in one grade IV and one grade

V. In higher grades (IV and V) urinary leakage and blood loss were the most common complications.
Urinomas was recorded in 14 children (3 gr III; 7 gr IV; 4 gr V).
Blood loss was important in 12 children with subsequent low hemoglobin serum levels (2 gr III; 5 gr IV; 5 gr V).
Early hypertension was recorded in 3 children (2 gr III, one gr IV) within the first month after renal trauma. Hypertension was transitory in two children and required no medication. One child was put on medication that helped normalize pressure values.
Two children developed vascular complications after their trauma: one grade IV developed pseudoaneurysm which was treated by embolization. One grade V had thrombosis of a renal artery requiring nephrectomy.

Graph 12 shows blood loss according to the grade of injury and management.
Blood transfusions were performed in 6 of 12 children (50%) (3 grade IV and 3 grade V).
No grade III needed blood supply. Among the children with low hemoglobin serum levels, 4 developed hypertension (2 gr III, one gr IV and one gr V). In one grade III hypertension developed within the first month after renal injury and resolved rapidly after medication.
Three other children developed late hypertension. Two of them underwent minimal invasive management: embolization in one grade IV, and arterial stenting in one grade V. Both grade III had non-operative management.

Late complications occurred such as shown in Figure 11. 9 grade III, 7 grade IV and 9 grade V, at various time after kidney injury.
Pyelic ectasia was the most frequent late-occurring complication (one gr I; one gr III; 2 gr IV; 2 gr V), and could be observed by ultrasound up to eleven years following trauma, in association with PUJ stenosis and VUR.

Late hypertension occurred in 3 children (one gr III, one gr IV, one gr V) between one and 5 years after trauma. In grade III, hypertension onset was 5 years post-injury. The child also developed renal cysts. In grade IV hypertension developed one year after renal injury and renal insufficiency. In grade V hypertension onset was 4 years after renal trauma.
Renal insufficiency occurred in two children (one gr IV, one gr V). Two years after kidney injury in both.
PUJ stenosis developed in three children after unsuccessful stenting (one gr IV; 2 gr V).
Late-developing calculus was recorded in 2 children (1 gr III and 1 gr V).
Hydronephrosis was also recorded in 2 children (one grade III, one grade V).

3.5 Long-term functional follow-up

3.5.1 Descriptive analysis

The mean overall follow-up duration (date of injury – date of the last renography) was 4.4 ± 4.3 (range: 0.2-11y) years. Considering each grade separately, the mean follow-up was 4.3 ± 5.6 years (range: 0.3-8.2y) in grade I, 2.6 ± 2.9 years (range: 0.3-5.8y) in grade II, 4.2 ± 5.6 years (range: 0.1-15.4y) in grade III, 4.9 ± 3.9 years (range: 0.2-11y) in grade VI and 5 ± 3.5 years (range: 0.3-10.3y) in grade V. The time of the follow-up tended to be longer in children with higher grade injuries (IV and V). Two children with grade I underwent a second renography only 8 years, 3 months after the first follow-up exam.

The first dynamic renography was performed 6.3 ± 15.5 (range: 0.1-88.6m) months after kidney injury. The interval between trauma and first renography was variable among the injury grades: 2 months (range: 0.2-4.2m) in grade I (n=2), 8.3 months (range: 1.7-18.9m) in grade II (n=3), 3.6 months (range: 1.6-12.4) in grade III (n=11), 3 months (range: 1.6-6.6) in grade IV (n=9) and 13.5 months (range: 0.4-88.6m) in grade V (n=9). The period was longer in higher injury grades. Among the 3 children with grade II injuries, one child had a single renography 18.3 months after trauma. In grade V, two children who required nephrectomy, underwent their first renography only 8 months in one and 7.3 years in after the date of the accident.

On average, each child underwent 3 ± 1.9 (range 1-8) dynamic renographies. Considering each grade separately, the number of renographies performed increased with the degree of the injury: 1.5 in grade I; 1.7 in grade II, 3 in grade III, 3.3 in grade IV and 3.5 in grade V.

Graph 13 summarizes the mean overall follow-up, the period of time between the date of the accident and the first renography as well as the average number of renographies each child underwent.

Relative renal function of the injured kidney at the first follow-up renography was 47 ± 3% (range: 45-49%) in grade I, 44 ± 2% (range: 42-46%) in grade II, 35 ± 13% (range: 10-50%) in grade III, 32 ± 14% (range: 8-48%) in grade IV and 25 ± 17% (range: 3-48%) in grade V. The relative function of the injured kidney depended on injury grade: relative function of the injured kidney was abnormal in 20 of 28 kidneys with grade III to V injuries.
Relativ renal function of the affected kidney at the last follow-up was 46 ± 3.5% (range: 44-49%) in grade I, 45 ± 2% (range: 42-46%) in grade II, 34 ± 15% (range: 0-50%) in grade III, 31 ± 17% (range: 12-47%) in grade IV and 24 ± 16% (range: 6-44%) in grade V. The last dynamic renography showed that the differential renal function was also related to injury grade. Compared to the initial relative kidney function assessment, we observed a decrease at last renography with a compensatory increase of relative function of the contralateral non affected kidney. The mean relative function of the unaffected side was also increased at last renography. Graph 14 shows mean relative kidney function of the injured side and uninjured side considering each injury grade.

Table 1 summarizes mean relative renal function and mean accumulation indexes of the injured and uninjured kidney for each injury grade, at first follow-up.
Table 2 summarizes mean relative renal function and mean accumulation indexes of the injured and uninjured kidney for each injury grade, at last follow-up.

3.5.2 Accumulation indexes and relative renal function of impaired and contralateral kidney

The left accumulation index and relative renal function in left kidney injury are shown in figures 15 and 16: the red line expresses left accumulation and relative renal function in left kidney injury as a function of time.
The left accumulation index and left relative renal function tended to decrease in both groups I-III and IV-V although the decrease is stronger in group I-III.

The right accumulation index and right relative renal function in left kidney injury are shown in figures 17 and 18: the right accumulation index tended to increase as a function of time in both groups I-III and IV-V after left kidney injury. This suggests compensation by the contralateral kidney, but there is no statistical evidence. Right relative renal function also tended to increase after left kidney injury in group I-III whereas in group IV-V right relative renal function tended to decrease after trauma.

Figures 19 and 20 show the right accumulation index and right relative renal function in right kidney injury as a function of time.
The right accumulation index and right relative renal function decreased after right kidney injury in group I-III, wherease the right accumulation index and right renal function tended to increase in group IV-V.

Figures 21 and 22 show left the accumulation index and relative function of the left unaffected kidney, in children with right kidney injury as a function of time.
The left accumulation index after right kidney injury tended to be steady as a function of time in group I-III, whereas the left accumulation index and left renal function tended to decrease in group IV-V.

Right relative renal function was 16.4% lower after surgical treatment in right kidney injury, independently of grade and time. (95% CI, 0.18-32.6, $p=0.047$).
In right kidney injury, and congenital abnormality, right renal function decreased by 25.6% (95% CI, 3.6-47.4, $p=0.023$). Table 1
Left relative renal function was 16.4% higher after surgical treatment in right kidney injury. (95% CI, 0.18-32.6, $p=0.047$). Left renal function increased by 25.6%, in right kidney injury with congenital abnormality/underlying disease. (95% CI, 3.6-47.4, $p=0.023$). Table 2

In right kidney injury following surgical treatment, the left accumulation index increased by 5.5% (95% CI, 3.9-7.2, $p<0.05$).
In right kidney injury, with underlying kidney disease, the left accumulation index increased by 7.1%. (95% CI, 5.2-8.9, $p<0.05$). Table 3

In left kidney injury, the left accumulation index decreased by a factor of 2.8 for injury grade IV-V compared to grade I-III. (95% CI, 1.13-4.6, $p=0.001$).

4. Discussion

Demograhics

In our study, the patients demographic was similar to that provided by Grimsby GM et al. (17): all renal injuries were blunt. The mean age at time of injury was 11.5 years (mean 11.5; median 10.6). The series included more boys than girls (22 boys, 11 girls). Compared to Grimsby GM et al. our population included a majority of grade III and higher-grade (IV-V) renal injuries (11 grade III, 9 grade IV and 8 grade V). This distribution is due to the fact that high grade kidney injuries were refferd to the University Hospital of Lausanne.

Congenital abnormalities

Pyelo-ureteral junction (PUJ) stenosis, polycystic kidney or congenital abnormalities like horseshoe kidney, unique congenital kidneys are not an uncommon finding, occurring in 1-23% of kidney injury cases (18). Hydronephrosis with concomitant stenosis of PUJ, intracystic hemorrhage or horseshoe kidney are the most frequently encountered situation discovered at the time of renal trauma (19). These situations are amenable to higher rates of complication such as renal pedicule avulsion in case of PUJ stenosis or bleeding, even in case of minor kidney injury. However, patients with PUJ stenosis and renal trauma do not necessarily have hematuria: in 31% hematuria is not reported because stenosis is said to limit blood flow.

Our study included three patients (9.1%) with anomalies of the urinary tract: one child with PUJ stenosis and hydronephrosis at time of admission, one horseshoe kidney and one unique congenital kidney. The child with PUJ stenosis had a minor kidney injury (grade I) with concomitant hematuria. The injury resulted from sports activity. Kidney injury was secondary to MVA in the child with horseshoe kidney and to motocross accident in the child with a congenital unique left kidney. In both injuries resulted from high velocity. The may be an explanation for the severity of their trauma (grade IV).

Hematuria

Szmigielski W. et al reported that there is no correlation between hematuria and the severity of kidney injury. Gross hematuria is said to be more predictive of major renal injury, but the absence of hematuria does not preclude significant renal injury. In some cases of renal artery thrombosis (24%) and PUJ stenosis (30%) hematuria has not been recorded(19). Buckley JC et al. reported gross hematuria in minor renal injuries and minimal or no hematuria in severe (grade IV and V) injuries (20). Given the inhomogeneous distribution of grades as well as the lack of information in 5 patients, we recorded the number of children with and without hematuria without making a distinction between micro- and gross hematuria.

Associated injuries

According to previous reports, associated injuries occure in 35% to 65% (21). In the present series associated injuries occured in 24 children (72.7%). Considering injury grades III-IV, and even higher rate of children, namely 85.7% had associated injuries. The first observation is that associated injuries are more numerous with increasing injury severity. The percentage of children with associated injuries was higher than that found in previous reports. Our population consisted mainly of grade III or higher-grade injuries compared to the literature, which explaines the high rate of associated injuries.

Management

Diagnosis and management of kidney injury in children, have widely discussed. Authors agree on a more conservative approach even for higher grade injuries. According to Nguen MM. al. children with a history of abdominal pain following a direct hit on the flank or secondary to high-velocity trauma (fall from height, MVA) should benefit from CT-scan imaging. CT-scanning has become the gold standard for the detection and classification of renal trauma (19). CT-scanning improved the grading of renal injuries because it allows a better distinction of renal parenchyma from surrounding tissue, helps identify necrotizing tissue and determinine the amount of extravasating contrast material, and also detects associated injuries(19)(22). Imaging is indicated if urinanalysis is positive for microhematuria but also in normal urinary findings when circumstances suggest kidney injury(18), because absence of minor bleeding does not exclude high-grade kidney injury (2). Observation consisting of urinanalysis and control CT-scan after 48 hours is the rule when there is no suspicion of severe kidney injury. In case of hemodynamic instability, UIV is performed to ascertain contralateral kidney function remains preserved.(2)

Buckley JC, McAninch proposed a management protocol for kidney injuries (3).
Non-operative management in grades I to III is considered safe. Hospital stay is not longer needed in grade I injuries, when there is no minor bleeding. On the other hand, a 24-hour hospital stay is recommended in grades II and III because these patients are at high risk of bleeding. Close monitoring and bed rest is the routine for all injuries from I to III if urinanalysis are positive for bleeding at admission.
In this study 11 of 16 children (majority) with low-grade injuries (I to III) were managed non-operatively. Ureteral stenting was necessary in 3 children with grade III injury. One child (grade III) went for late surgery (partial nephrectomy, pyeloplasty). Immediate surgery was necessary in two: one grade I because of PUJ stenosis and hydronphrosis, one grade III with hemodynamic instability went for surgical exploration and subsequent renorraphy.
Our results correlates with those published in previous reports: in a majority of cases, conservative, non-operative treatment was safe.

Management of higher-grade injuries (grade IV and V) is still debated. However, a study demonstrated the preservation of renal function up to 50% after conservative treatment of high-grade injuries(8). Surgery remains necessary in selected cases. Conservative (or expectant) management is largely accepted as long as the patient is hemodynamically stable. So-called expectant management consists of observance and resort to minimally invasive techniques to manage early occurring complications such as urinomas or persistent bleeding. Daniel D. Dugi proposed a substratification of grade IV injuries in one low-grade and one high-grade category based upon radiological findings (peri-renal hematoma, index of contrast extravasation and the site and complexity of renal fractures), and suggested a conservative approach for low-grade injuries and immediate surgery in case of compromising vascular lesions (23). These findings have been validated (24).
Grade IV to V, as defined by AAST(16), may result from high-velocity trauma because the forces exerted on the renal parenchyma are strong enough to cause vascular rupture of extra-renal vasculature and/or lesion of the renal pedicle. Therefore, these patient are at greater risk of important blood loss. The proportion of associated lesions is also higher in grade IV-V renal trauma (2). Patients with hemodynamic instability as such, unresponsive to liquide supply, or after more than 3 packed red blood cells transfusions, need to go for surgical exploration. Important blood loss is suggestive of major renal injury (shattered kidney, mulitple laceration) or life-threatening associated injuries.
In the present study minimal invasive management was majoritary among grades IV and V. Management followed the guidelines suggested by previous studies.
Management was minimally invasive in 12 children (7 gr IV, 5 gr) such as ureteral stenting and interventional radiology. Radiological procedures were performed in three children only.
Surgery was necessary in three children with grade V kidney injury: two nephrectomies and one vascular repair. Among these three, one grade was hemodynamically unstable at time of admission and went for surgical exploration before nephrectomy and splenectomy. Thrombosis of the renal artery led to nephrectomy in the other. No child with grade IV renal trauma needed surgery.

Early and late complications
Complications related to kidney injury occure in 3-33% (19)(18). Depending on injury grade and associated injuries, complications may be isolated, multiples, early or late occuring (18). Early developing complications appear within the first month after renal trauma, including urinary extravasation/ urinoma, infections (urinary, pyelonephritis), abscess and sepsis. Late

occuring complications appear after 4 weeks including hydronephrosis, calculus, cysts and renal insufficiency. Late bleeding secondary to pseudoaneurysm or arterio-venous fistula and hypertension may appear early or late.
In this study, early complications were frequent and numerous and included infection (fever, urinary infection pyelonephritis), one renal artery thrombosis and one pseudoaneurysm, transitory hypertension and urinomas. Late complications included pyelic ectasia, hydronephrosis, PUJ stenosis, cysts, late hypertension and renal insufficiency.

According to Goeffte et al. urinary extravasation is the most frequently occurring complication in expectant management (13-16%). According to AAST criteria, grade IV and V are defined by lacerations extending to the collecting system with a risk of urinary leakage.
In a minority (12-36%), urinoma does not resolve spontaneously and patients need either percutaneous drainage, so-called nephrostomy, or transureteral drainage by placing a ureteral stent (18)(21). Opinions differ concerning the advantage of one technique over the other. Comparing both techniques, transureteral drainage dimnishes the risk of stent dislocation as a percutaneous drain might be torn off easily. Percutaneous drainage also needs catheter care and urinary bag (18)(25).The minimally invasive approach is an option to maximize wound healing via collecting system reapproximation and limitation of parenchymal loss (26).
In our series, 14 children developped urinomas. All underwent ureteral stenting. In 3 children only (one grade IV and 2 grade V) drainage was problematic and the procedure had to be repeated. All three developped PUJ stenosis and underwent transitory nephrostomy (percutaneous drainage). Two grade V injuries underwent pyeloplasty for their stenosis. Grade IV had another successful ureteral stenting. Therefore, ureteral stenting can be considered as a safe and efficient technique for the drainage of urinoma.

Late bleeding is a severe and frequent complication that is mainly due to pseudoaneurysm or arterio-veneous fistula. Hematuria and/ or low hemoglobin signals continuing bleeding. However urinanalysis can be normal in case of blood clotting within the upper urinary tract. In the later case, obstruction may cause renal insufficiency. Injected CT-scan imaging is usually performed 3 or 6 months following kidney injury to document normal contrast enhancement. In case of extravasating contrast material, high suggestive of active bleeding, angiography is the preferred imaging tool to localize the site of the bleeding. Ongoing bleeding requires intervention because most pseudoaneurysm and arterio-veneous fistula do not resolve spontaneously (21). According to several authors, embolization of selective cases/ high grade renal injuries with vascular damage has been safe and effective (7)(27)(28).
In this study, late bleeding occurred in three children (one gr IV, 2 gr V). Management was minimally invasive: one embolization of pseudoaneurysm, one arterial balloon dilatation and arterial stenting. The child who underwent embolization did not rebleed but developed hypertension one year and a half after the date of the trauma. One year later the patient developped renal insufficiency (stage II according KDOQI to classification). Further follow-up included remler, cardiac echography and medication. The child who underwent baloon dilatation did well without any complications. Arterial stenting in one child did not succeed. Nephrectomy was not performed because the contralateral kidney had 97% remaining function. The child became hypertensive. MRA (magnetic resonance angiography) confirmed stenosis of renal artery.

Hypertension counts among the severe complications with regards to its systemic impact. Incidence of hypertension following kidney injury is not clearly defined. Some studies report no cases (7)(29) wherease others report incidence of 0.6-6% (1). Hypertension is said to be transitory in 6-10% according to Hosam S. Al Qudah et al. Three mechanisms causing hypertension have been observed and described : the « Goldblatt » mechanism, the « Page kidney » and post-traumatic arterio-venous fistula. All three result in increased renin serum levels secondary to decreasing renal plasmatic flow. The Goldblatt theory says that lesions of vessels can possibly evolve to stenosis compromising (RAS, renal artery stenosis) blood

perfusion of the kidney segment. Page kidney is due to compression exerted by hematoma, pseudoaneurysm, urinoma or even renal scars. In the last case, arterio-venous fistula have a direct impact on the renal blood flow. MR angiography and CT injected angiography are excellent test to detect renal artery stenosis with high sensitivity and specificiy) but doppler ultrasound is better in the hemodynamic assessment of renal artery stenosis (pressure measurments on distal artery stenosis)(14).
In this study, hypertension occurred in 6 of 33 children (18.2%). Early and transitory hypertension occured in three children, resolving spontaneously in two. In one hypertension was controlled by medication. Three children developped late hypertension : one grade III, one grade IV and one grade V. In grade III, a CT-scan was performed because of lower hemoglobin levels, but there was no evidence of ongoing bleeding. Therefore management remained non-operative. However, hypertension developed 5 years after renal trauma, and MRA showed post-ductal stenosis. Grade V underwent vascular stenting. This child developped hypertension 4 years following kidney injury. MRA confirmed renal artery stenosis

The incidence of post-traumatic renal failure after major renal trauma is approximately 6.5-10% (30). Two children in our series developed renal insufficiency (one gr IV, one gr V) 2 vs 4 years after renal trauma. The child with grade IV developed several complications such as pseudoanevrysm and hypertension before onset of renal insufficiency. The child with grade V required splenectomy besides nephrectomy. Blood loss was important. Renal insufficiency developed in the remaining kidney.

Hydronephrosis developps in 3% according to the authors of previous reports. The underlying mechanism of hydronephrosis is not well understood but PUJ stenosis is said to be a favoring factor. Pyeloplasty is necessary if the obstruction becomes symptomatic (pain) or compromises renal function. Our study included two children (6%) with hydronephrosis. One (gr V) had concomitant PUJ stenosis and underwent pyeloplasty.

In the literature no protocol is currently available regarding optimal renal functional follow-up. Questions remain as to how long investigations should be pursued and wether selected cases warrant closer follow-up. DMSA radionuclide imaging is commonly used to assess differential renal function (11)(31)(1)(8)(7)(32)(4)(33)(34). Differential renal function represents the contribution of each kidney to the sum of the left and right renal activity and normally ranges from 45% to 55% (35). Furthermore, it is standardized as follows: normal to mild impairment if the injured kidney achieves more than 40% of differential renal function; moderate impairment if the injured kidney provides 30-40% of differential function, and severe if the injured kidney contributes less than 30%. Renal function is considered sufficient if the kidney's contribution exceeds 30% because it would prevent renal failure in the event that the uninjured kidney was lost (9).
Several authors observed that renal function decreased in case of severe injuries compared to low-grade injuries, in which renal function remains mostly preserved (9)(8)(4)(11).
Few authors published any results of late renal functional follow-up (11)(32)(4).
Martin S. Keller showed that renal function after trauma depended on injury grade and that renal function remained unchanged at the one-year follow-up. Pereira Junior et al. concluded that grade III and IV parenchymal lacerations did better in terms of late renal function compared to grade IV and V with vasculare lesions. Fiard et al. also observed a better functional outcome in subtypes of grade IV involving parenchymal lesions.
Predictive factors of long-term renal function of grade IV patients were defined by Long et al. They concluded that the percentage of devascularized parenchyme (>25%) and the need for surgery were decisive and affected renal function.

In the present study I-123 OIH dynamic renal renography was performed for each child with kidney injury at the University Hospital of Lausanne.. Renal uptake of OIH (ortoiodohippuran) is proportional to the relative effective renal plasma flow. Ortoiodohippuran is secreted to an extent of 80% by the proximal tubulus and therefore provides a better visualization of kidney function, whereas DMSA is the radiotracer of choice for imaging renal cortex, for example in the assessment and follow-up of patients with chronic pyelonephritis (14).

Each child included in the study underwent 3 (range 1-8) dynamic renographies. The mean overall follow-up was 4.4 ± 4.3 (0.2-11y) years. Similarly to other reports, renal functional impairment depended on injury grade: 47 ± 3% (range: 45-49%) in grade I, 44 ± 2% (range: 42-46%) in grade II, 35 ± 13% (range: 10-50%) in grade III, 32 ± 14% (range: 8-48%) in grade IV and 25 ± 17% (range: 3-48%) in grade V. Relative renal function of the unaffected kidney was increased compared to the injured side. At last follow-up, the relative kidney function of the injured side also depended on grade of injury and was decreased compared to the first functional assessment except for grade II injuries.

Statistical analysis of accumulation indexes and renal function over time in left and right kidney injury did not confirm our prior hypothesis. Even though a trend towards functional loss was observed in left kidney injury for all grades (I-V), no statistically significant results could sustain the hypothesis. An increase in right accumulation index and right renal function was observed in left kidney injury for grades I-III, suggesting contralateral compensation, but these results were not statistically significant.
In right kidney injury, a decrease in right accumulation index and right relative renal function was observed in grade I-III, whereas the right accumulation index and right renal function was increased in group IV-V. Analysis were not significant. No contralateral compensation ,neither left accumulation index nor left renal function, by the left kidney was observed in right kidney injury for all grades (I-V).

Further analysis showed that surgical management (invasive and /or minimally invasive), regardless of the grade and time, was associated with a decrease of right relative kidney function, with an increase of left accumulation index as well as an increase of left relative kidney function. In right kidney injury, renal congenital abnormalities were associated with a decrease of right relative kidney function and an increase of left relative kidney function.

This study was limited by the small number of cases as well as the inhomogenous grade distribution. There was also a lack in post traumatic functional assessment. Nevertheless an average of 3 renographies could be performed in each chidren with an average follow-up period of 4.4 years

5. Conclusion

The majority of children included in our study had mild to severe kidney injuries (III-VI). The fact that the University Hospital of Lausanne is the referral trauma center of high-grade kidney injuries explains this distribution. Grade IV and V injuries resulted from high-velocity trauma such as falls from height or motor vehicle accidents (MVA). Grade III injuries resulted from sports activity in most cases. Most MVA occurred among grade V injuries. Associated injuries were frequent, occurring in 72.7% of children with grade III-V injuries.

The protocol for renal trauma in our institution has been very conservative for more than 2 decades and includes immediate surgery only in case of hemodynamic instability or very severe renal damage (« shattered kidney »). Bed rest and clinical observation are applied to all hemodynamically stable patients. Once the injury is graded with CT images, the child will undergo renal decompression or drainage only in cases of persistant urinary leakage with growing urinoma. Late CT images or ultrasonography is used for the assessement of urine extravasation.

Complications were numereous and varied : 14 out of 33 children developed urinoma managed by transureteral drainage that was efficient in 11 children. In two children, stenosis of the ureteropelvic junction developped. Late pyeloplasty was performed in both.

Hypertension occurred in three patients without consequences in two of them. In a third patient, blood pressure was controlled by medication.

Late complications were less frequent. Hypertension and kidney failure were recorded in three and two patients, one year for hypertension and 4 years for kidney failure following renal trauma. These complications, due to their functional and systemic impact, warrant nephrological and cardiological follow-up. Calculus, cysts or pyelo-calicial dilatation were recorded lately. In the latter case, radiological monitoring is warranted because of possible obstruction, malignancy (Bosniak cysts classification) and functional kidney impairement.

In regards to the frequency, diversity and severity of these complications, regular clinical and radiological follow-up is necessary. Clinical examination must look for signs such as flank pain, reccurent hematuria, complicated urinary tract infection and anormal blood pressure measurments. Ultrasound imaging or CT-scanning should be performed up to 3 months following renal trauma to detect hyperechoic structures, dilatation or stenosis. If reno-vascular hypertension is suspected, Doppler ultrasound will best assess renal vascular flow, eventually MRA for the imaging of vascular stenosis. In the later case Remler confirms hypertension. Cardiological and nephrological follow-up involves regular echocardiography (structural, morphologic and functional changes),blood pressure measurments, as well as urine analysis.

Regular and long-term follow-up using I-123 OIH dynamic renal renography was valuable for kidney functional assessment : our descriptive analysis showed that relative renal function was grade dependent and that relative kidney function taken at last functional assessment was decreased compared to that of the initial assessment, with an increase of contralateral kidney function (RF).

Statistical analysis of accumulation indexes and relative kidney function of left and rigth kidney injury did not confirm the prior hypothesis suggesting a decrease of kidney function as a function of time, even though a decreasing tendency in left and right kidney injury was observed. However this study was limited by the small number of children, the inhomogenous grade distribution as well as the variability of each child within the same grade of injury. Nevertheless, further analysis showed that surgery and congenital abnormalities had an impact on left accumulation index as well as left and right relative kidney function.

Figures and tables :

Figure 1: Distribution of injury mechanism expressed in percentage.
Sports activity included bicycle, motocross, skateboard and ski.

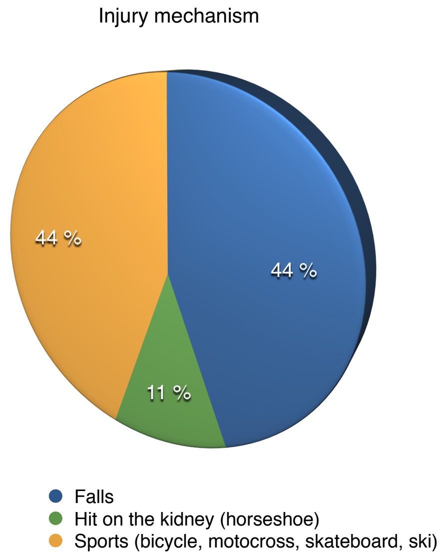


Figure 2: Distribution of children according to the mechanism of injury and grading of renal trauma.

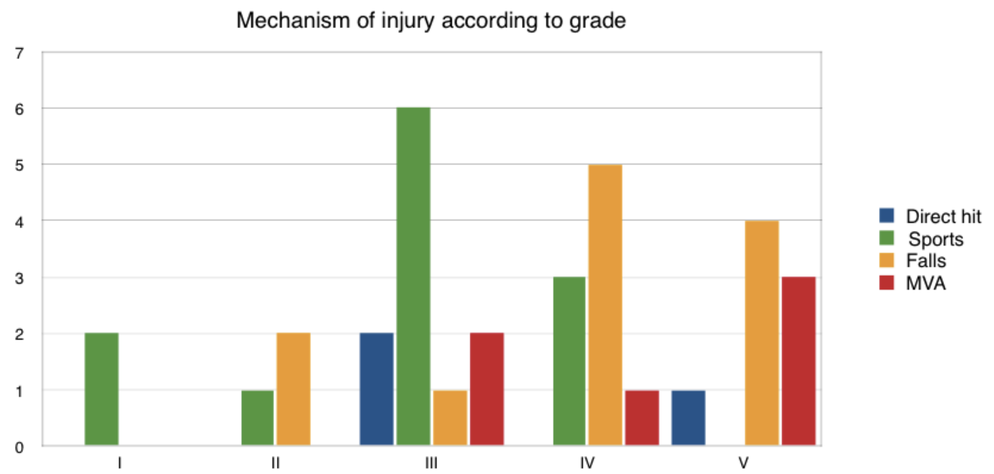


Figure 3: Distribution of children with and without hematuria (gross or microscopic) according to the grade of renal injury.

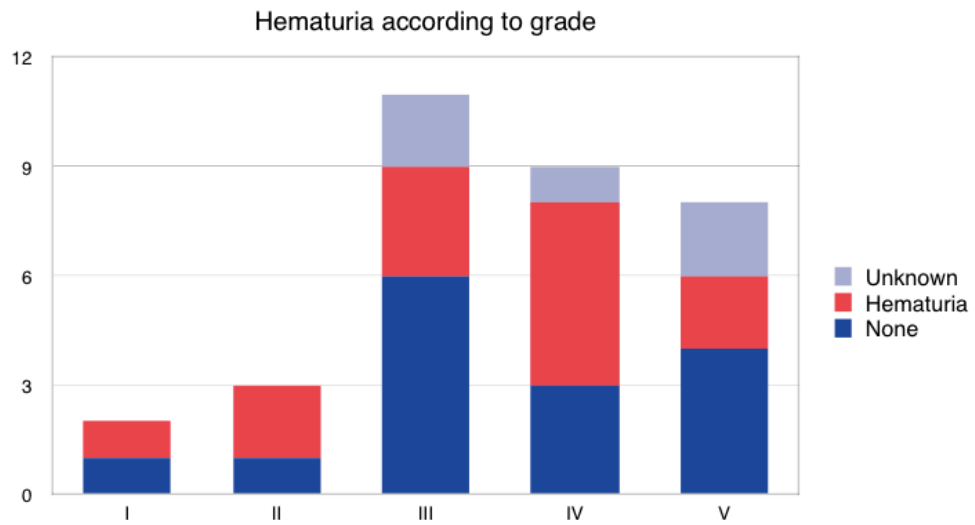


Figure 4: Distribution of the associated injuries according to the grade of renal trauma. One patient can have multiple injuries

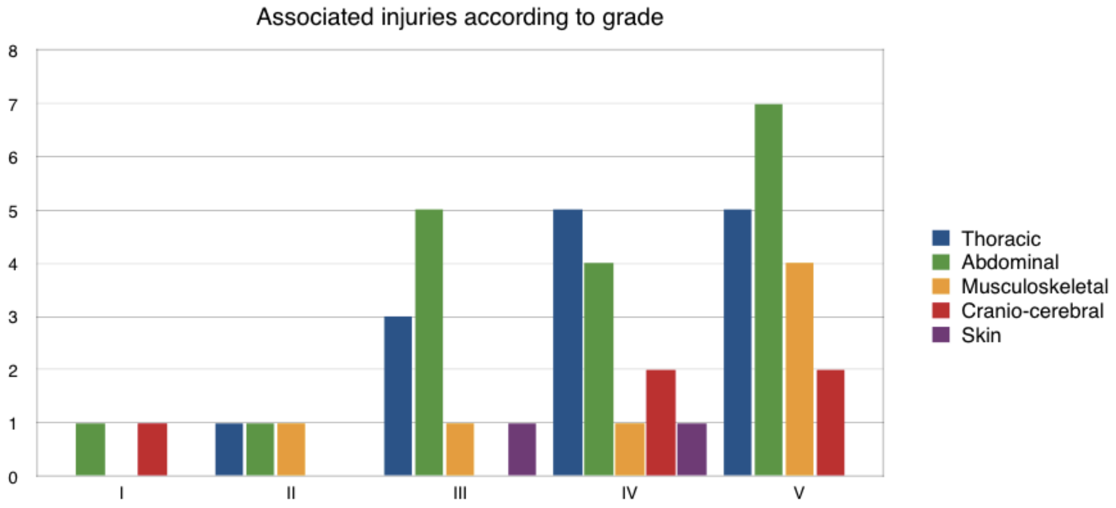
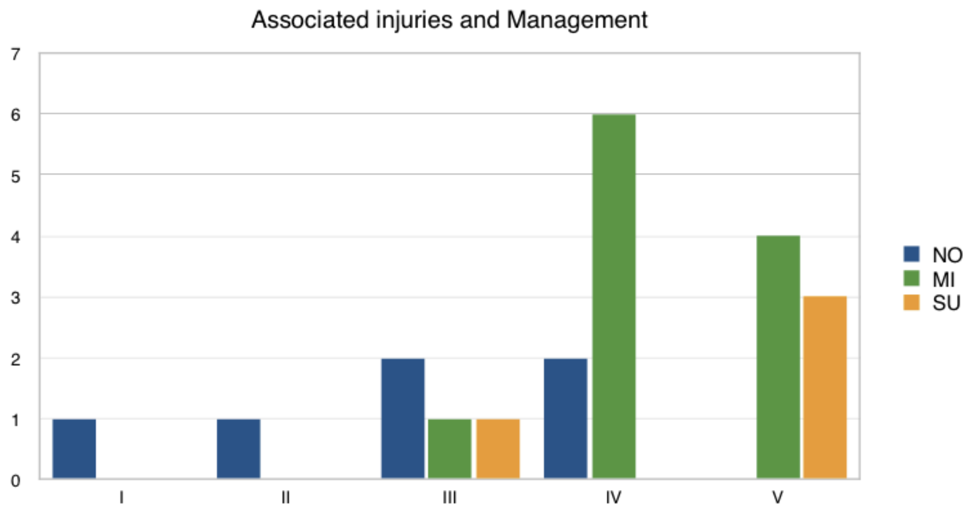


Figure 5: Distribution of associated injuries according to the type of management (NO: non-operative, MI: minimally invasive, S: surgical) and the grade of renal injury.



*

Figure 6: Distribution of the type of management (NO: non-operative, MI: minimally invasive, S: surgical) according to the grade of injury. * Congenital pyelo-ureteral stenosis

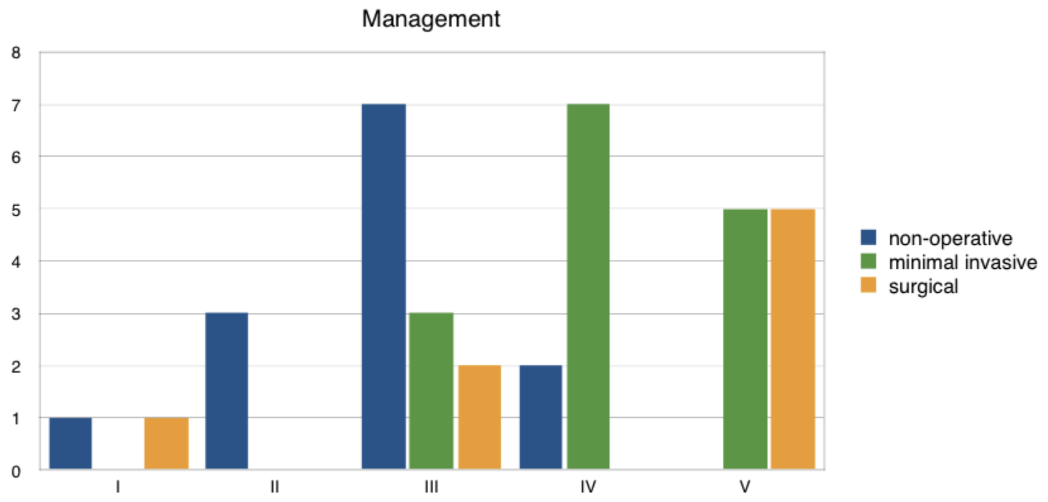
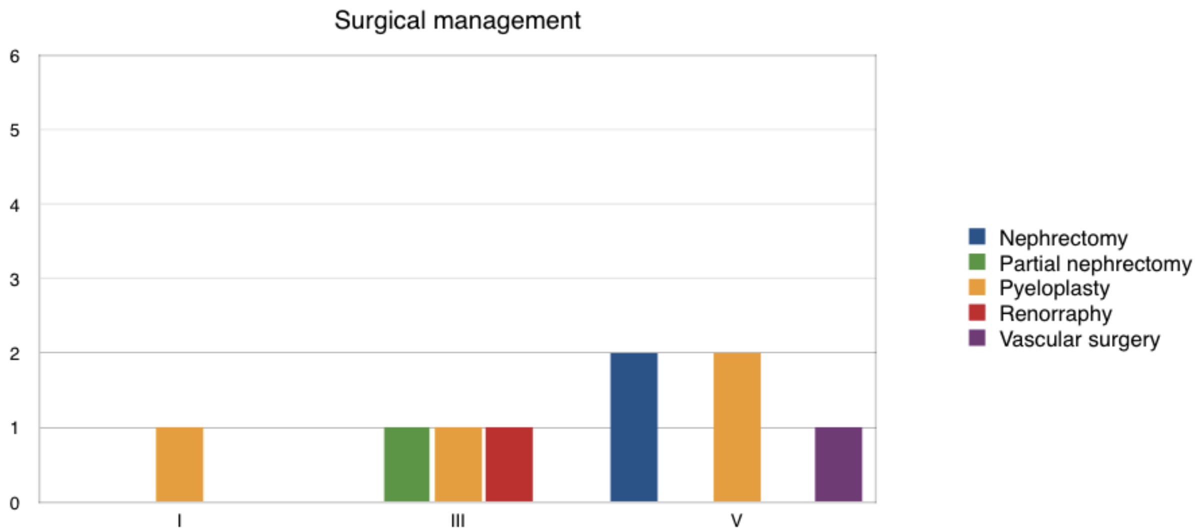
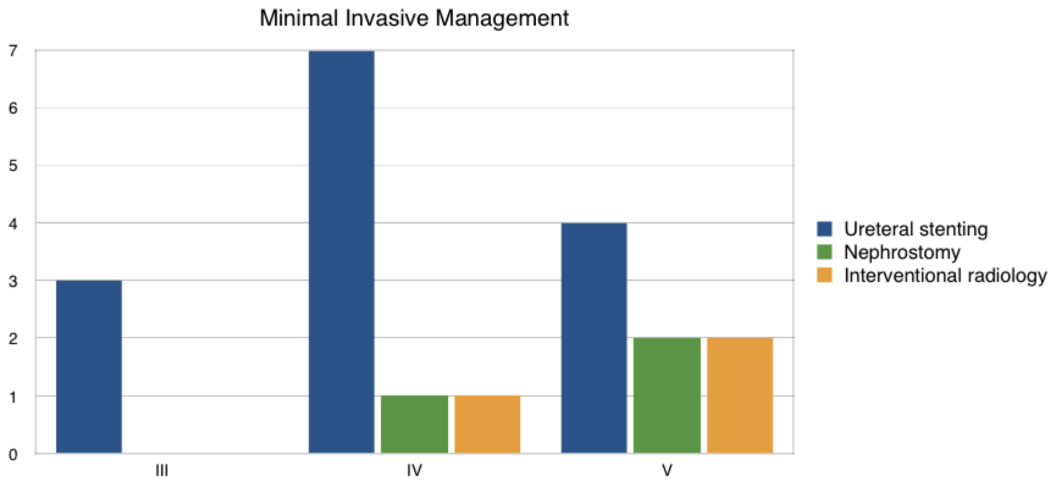


Figure 7: Surgical management according to the grade of injury



Grade I with underlying renal abnormality (PUJ stenosis) requiring early pyeloplasty. Grade III with hemodynamic instability and renorrhaphy. Grade III requiring late pyeloplasty and partial nephrectomy for delayed complications (calculus, UPJ stenosis 7 years post-injury). Grade V: two nephrectomies, one vascular repair.

Figure 8: Distribution of the children with minimally invasive treatment according to the type of minimally invasive procedure and the grade of injury.



Ureteral stenting was performed during cystoscopy. Nephrostomy was performed percutaneously with general anesthesia. Interventional radiology included arterial stenting in one, arterial balloon dilatation in one and aererial embolization in one.

Figure 9: Distribution of complications according to the type of management and grade of renal trauma.

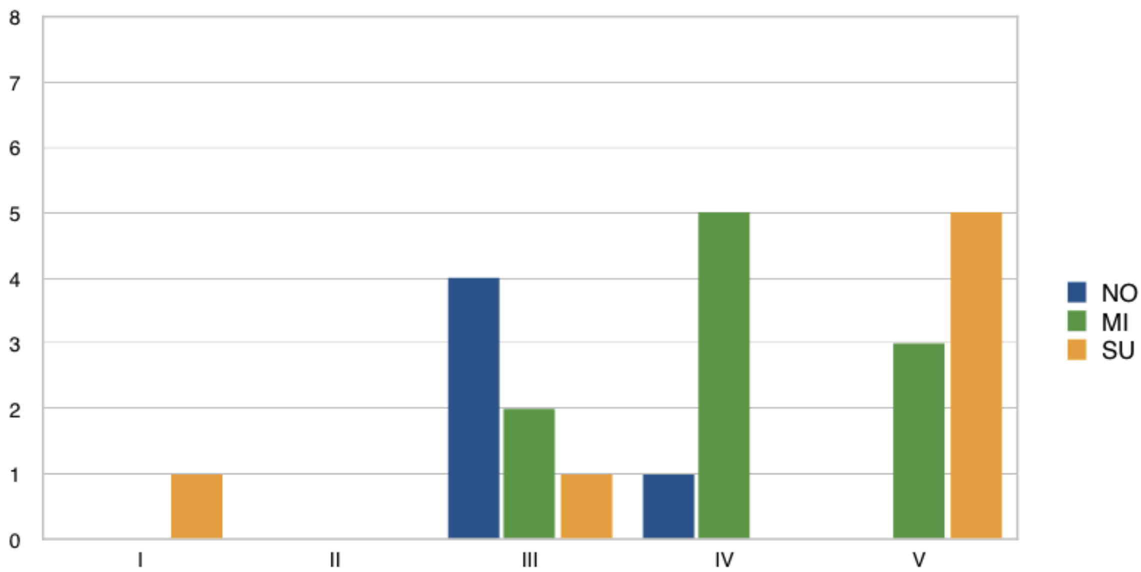
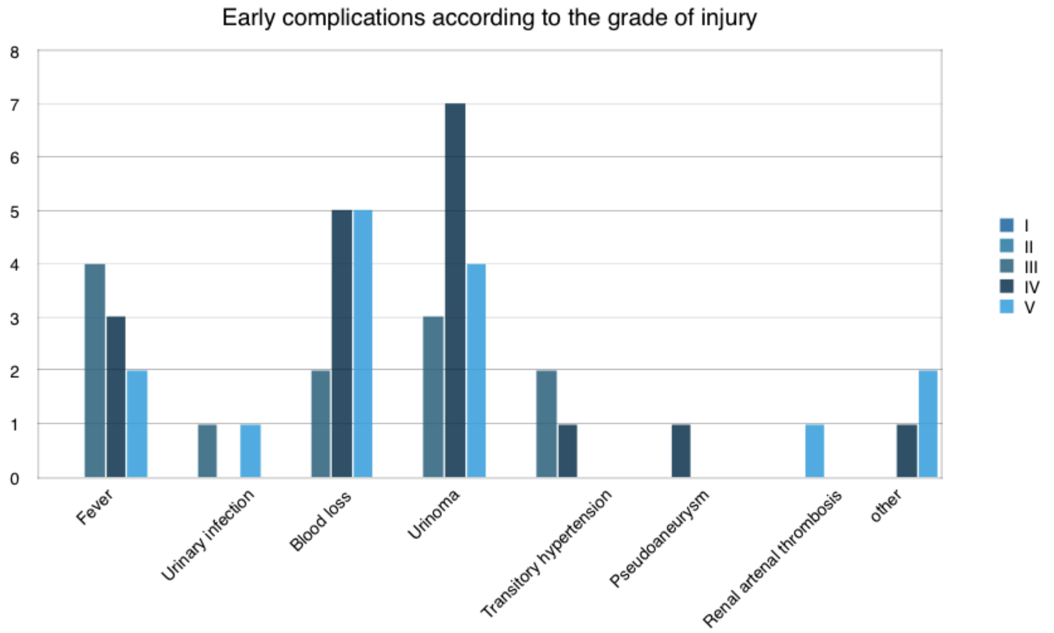
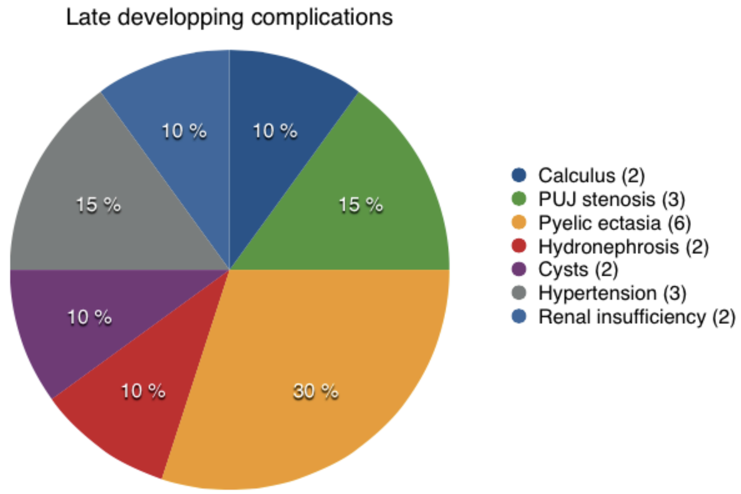


Figure 10: Distribution of early complications according to grade III to IV



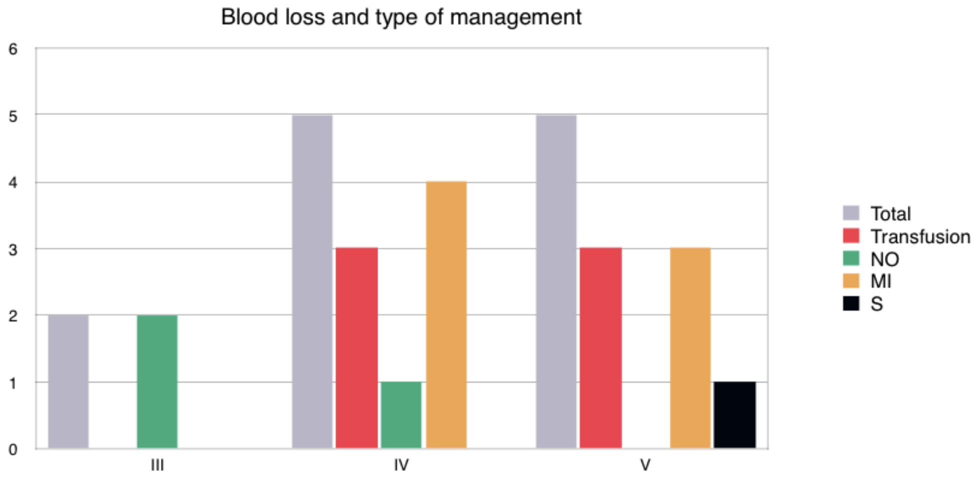
Urinary leakage and blood loss were frequent in high-grade injuries (IV-V). Transitory hypertension in three with spontaneous resolution in two (gr III/ IV), under medical control in one (gr III).
Vascular complication occurred twice (IV and V). Urinary infection and pyelonephritis were rare. Fever was most frequent in grade III.

Figure 11: Distribution of late occurring complications.



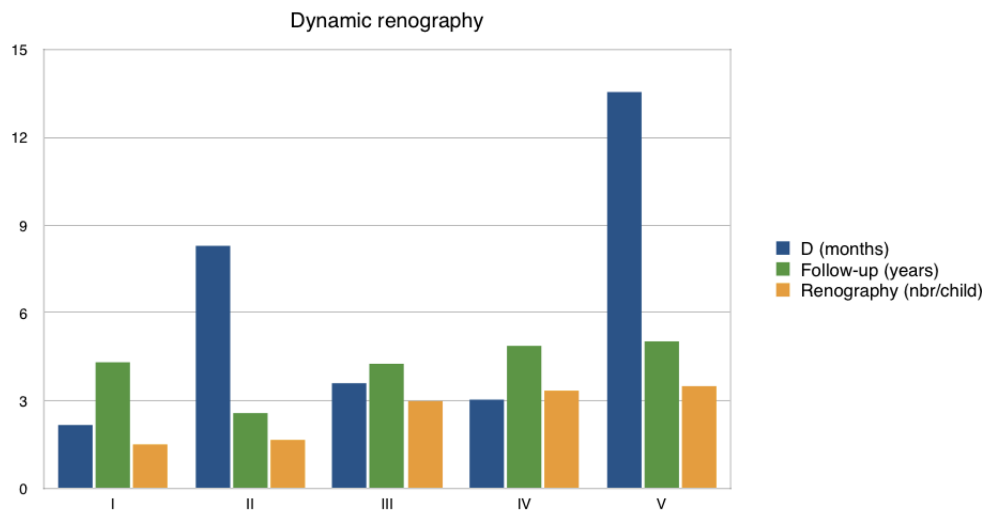
No grade II developed complications.
The most frequent finding was pyelic ectasia occurring almost in all grades except grade II.

Figure 12: Blood loss according to grade of injury and type of management



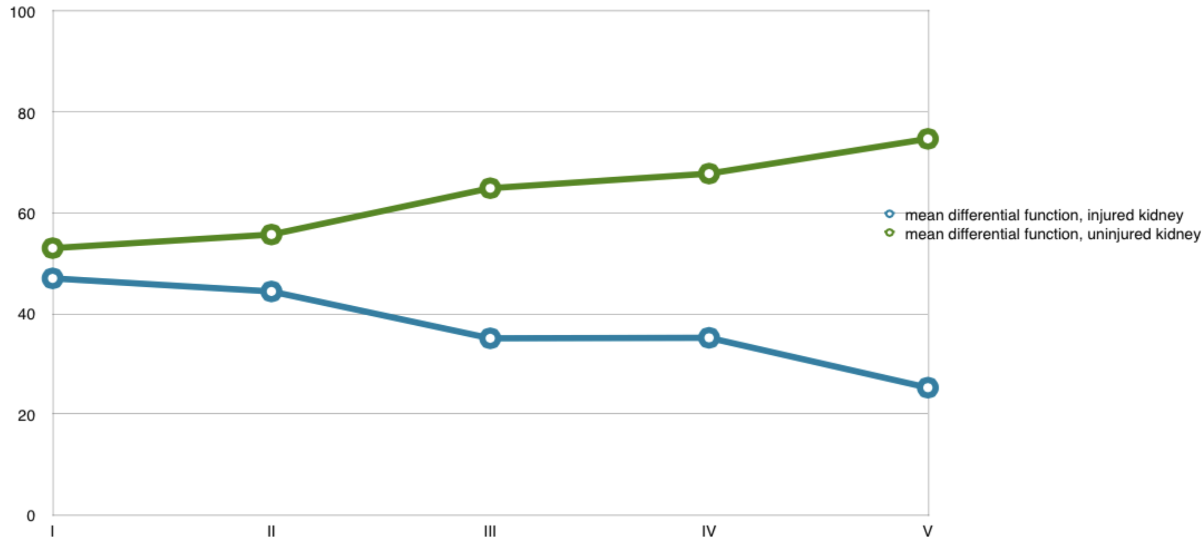
In grade IV and V, three children required blood transfusions. No grade III needed transfusion. Hypertension developed in four: one grade IV (s/p embolization) one grade V (s/p vascular stenting), and two grades III children (non operative management).

Figure 13: Dynamic renography according to the grade of injury



D: period between the accident and the first renography (months)
In higher injury grades follow-up time is slightly longer and more renographies are performed.

Figure 14: Mean relative kidney function according to injury grade at first renography



Decrease in mean relative kidney function and increase in mean relative kidney function of the uninjured kidney. Decrease depends on injury grade.

Table 1: First follow-up

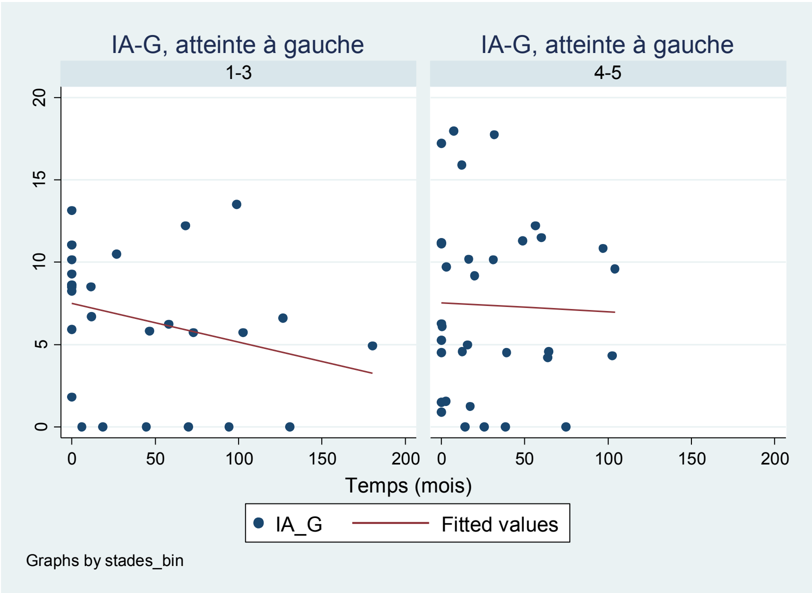
Injury grade	Age (mean ± SD)y	AI_IK	AI_CK	RF_IK (%)	RF_CK (%)
I (n=2)	12.2 ± 3.9y	9.45 ± 0.27	10.64 ± 0.7	47 ±3	53 ± 3
II (n=3)	13.4 ± 1.9y	8.88 ± 0.4	11.15 ± 0.2	44 ± 2	56 ± 2
III (n=11)	12 ± 3.1y	7.29 ± 4.2	12.03 ± 2.5	35 ±13	65 ± 13
IV (n=9)	11 ± 3.3y	5.43 ± 2.9	13.15 ± 2.9	32 ±14	68 ± 14
V (=8)	13.5 ± 2.7y	5.62 ± 4.2	15.00 ± 1.5	25 ±18	75 ± 18

AI_IK: accumulation index of the injured kidney; AI_CK: accumulation index of the contralateral kidney.
RF_IK: diferential renal function of the injured kidney; RF_CK: differential renal function ot the contralateral kidney

Table 2: Last follow-up

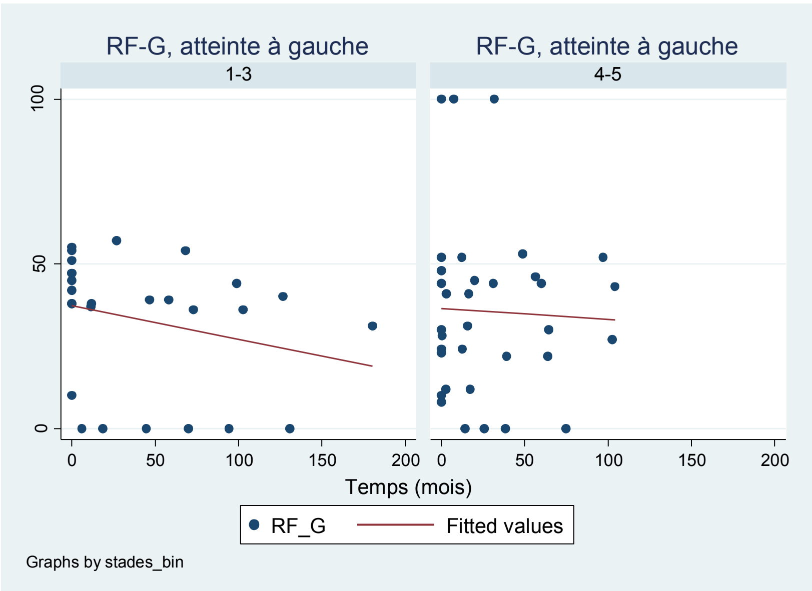
Injury grade	Age (mean ± SD)	AI_IK	AI_CK	RF_IK (%)	RF_CK (%)
I (n=2)	16.3 ± 1.9	10.14 ± 0.7	11.82 ± 2.4	46 ± 3	54 ± 3
II (n=3)	15.3 ± 3.5	9.30 ± 0.9	11.54 ± 0.6	44 ± 2	56 ± 2
III (n=11)	15.9 ± 3.6	7.31 ± 4.5	13.01 ± 2.7	34 ± 15	66 ± 15
IV (n=9)	15.6 ± 1.7	7.84 ± 5.7	12.11 ± 3.3	31 ± 17	69 ± 13
V (n=8)	17.4 ± 2	5.13 ± 4.4	14.55 ± 1.7	24 ± 16	76 ± 16

Figure 15: Left accumulation index in left kidney injury as a function of time.



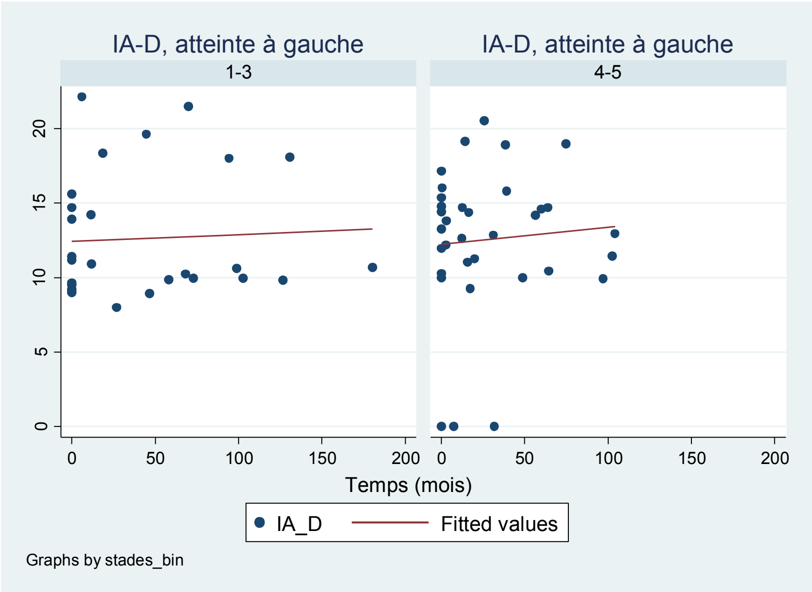
X-axis: time expressed in months since the date of injury
Y-axis: accumulation index value
Left accumulation index in left kidney injury in I-III kidney injuries, and IV-V kidney injuries.
Regression line of fitted values given by the red coloured line.
Decrease of the accumulation indice in groups I-III and IV-V.

Figure 16: Left renal function in left kidney injury as a function of time.



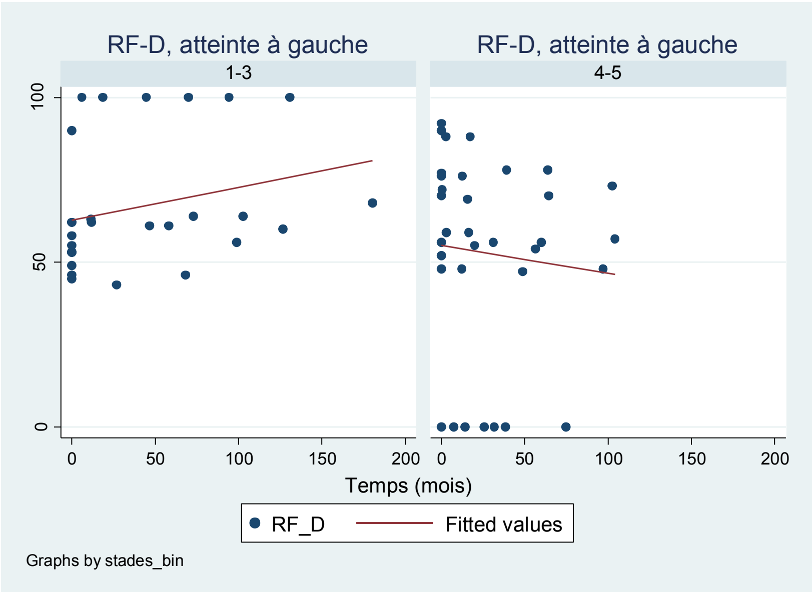
X-axis: time expressed in months, 0 being the date of injury/ since the date of trauma
Y-axis: relative renal function expressed in %
Left accumulation indice in left kidney injury as a function of time in I-III kidney injuries and IV-V kidney injuries. Regression line of fitted values given by the red coloured line.
Decrease of the accumulation indice in groups I-III and IV-V.

Figure 17: Right accumulation index in left kidney injury as a function of time.



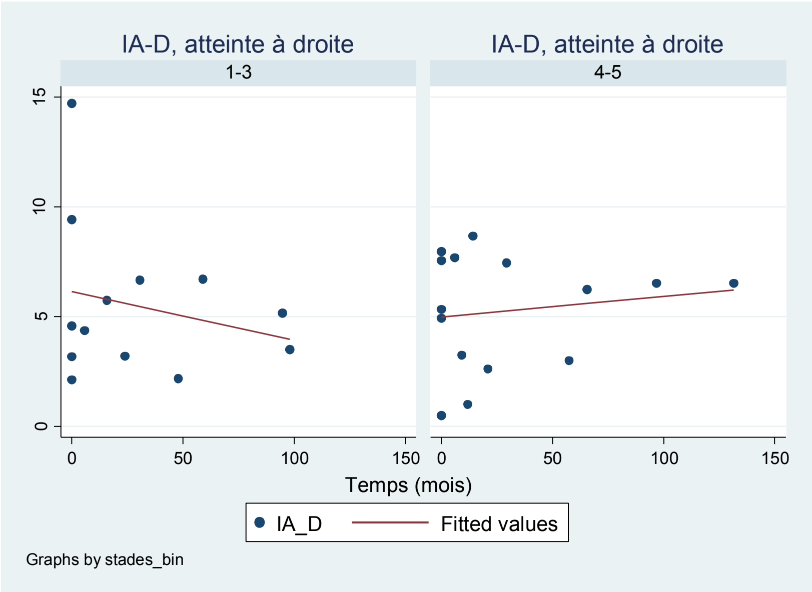
Increase of the right accumulation index as a function of time in groups I-III and IV-V.

Figure 18: Right renal function in left kidney injury as a function of time.



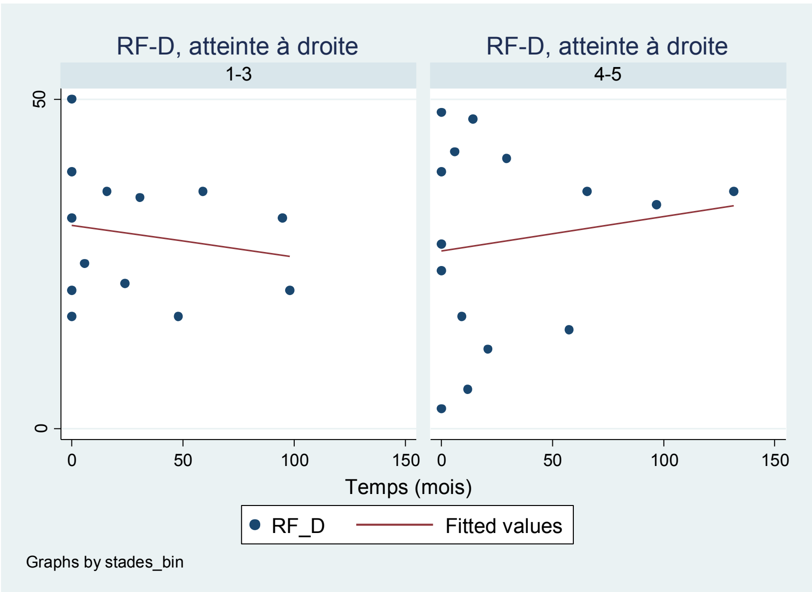
Increase of right renal function in as a function of time in group I-III; decrease of right renal function in group IV-V.

Figure 19: Right accumulation index in right kidney injury as a function of time.



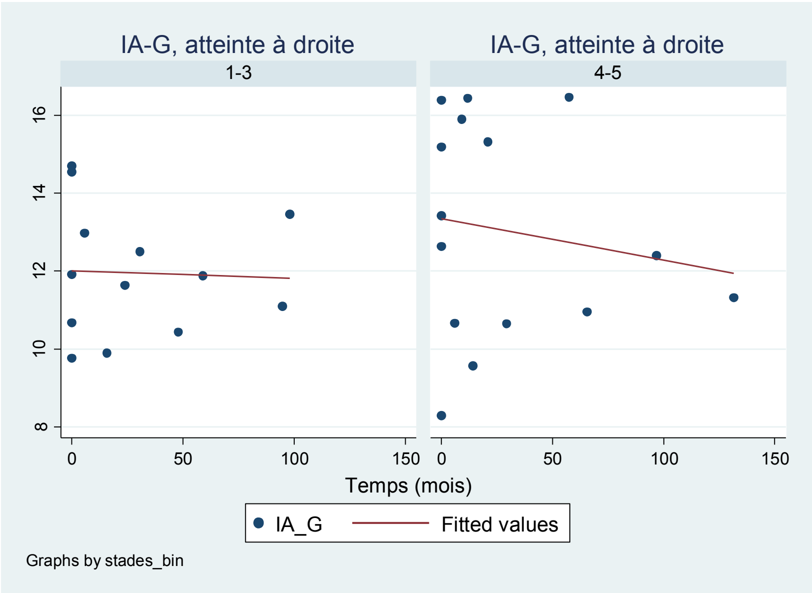
Decrease of right accumulation indexe in group I-III, increase of right accumulation index in group IV-V.

Figure 20: Right renal function in left kidney injury as a function of time.



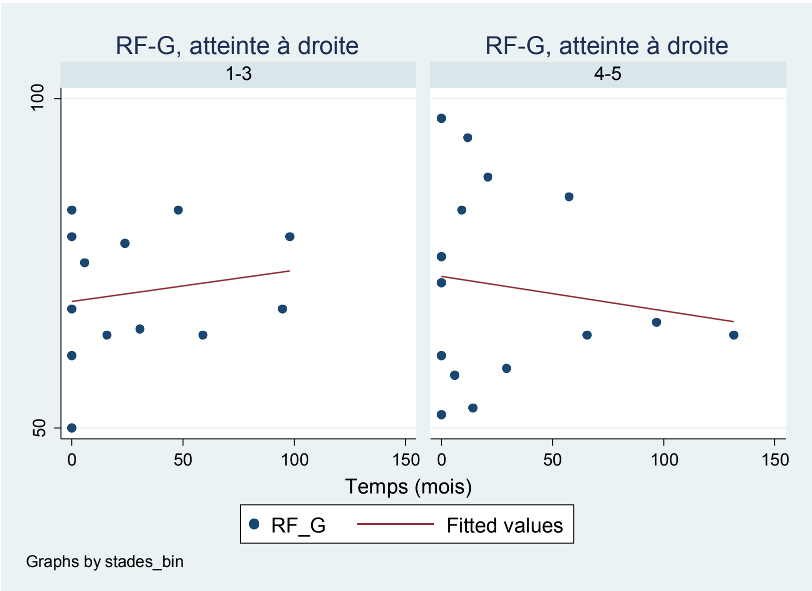
Decrease of right renal function in group I-III, increase of right renal function in group IV-V.

Figure 21: Left accumulation index in right kidney injury as a function of time.



Left accumulation index in right kidney is almost steady in group I-III, decrease of left accumulation indice in group IV-V.

Figure 22: Left renal function in right kidney injury as a function of time.



Increase of left renal function in group I-III, decrease of left renal function in group IV-V.

Table 3:

```
xtgee rf_d i.stades_bin temps_m stadebin_temps age fille chir autresdiag compl
if rein ==1, family(gaussian) nolog

GEE population-averaged model                   Number of obs      =        28
Group variable:                        ipp      Number of groups   =        10
Link:                             identity      Obs per group: min =         1
Family:                           Gaussian                     avg =       2.8
Correlation:                  exchangeable                     max =         6
                                                Wald chi2(8)       =     18.29
Scale parameter:                  76.27317      Prob > chi2        =    0.0192

------------------------------------------------------------------------------------
          rf_d |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------+--------------------------------------------------------------------
    stades_bin |
          4-5  |   6.198667   7.981792     0.78   0.437    -9.445359    21.84269
       temps_m |  -.0126925   .0437215    -0.29   0.772    -.0983851        .073
stadebin_temps |  -.0364772   .0571538    -0.64   0.523    -.1484966    .0755422
         age_y |  -2.059512   .9296017    -2.22   0.027    -3.881497   -.2375257
         fille |  -4.117839   8.432864    -0.49   0.625    -20.64595    12.41027
          chir |   -16.4003   8.273617    -1.98   0.047     -32.6163   -.1843125
    autresdiag |  -25.49619   11.17688    -2.28   0.023    -47.40248   -3.589904
         compl |   10.62481   6.408625     1.66   0.097    -1.935861    23.18549
         _cons |   79.82261   16.85364     4.74   0.000     46.79008    112.8551
```

Red: Decrease of right renal function by 16.4% in right kidney injury, independently of grade and time, after surgical treatment. (95% CI, 0.18-32.6, p=0.047).
Green: Decrease of right renal function by 25.6%, with congenital anomalities (95% CI, 3.6-47.4, p=0.023).

Table 4:

```
. xtgee rf_g i.stades_bin temps_m stadebin_temps age fille chir autresdiag compl
if rein ==1, family(gaussian) nolog

GEE population-averaged model                   Number of obs      =        28
Group variable:                        ipp      Number of groups   =        10
Link:                             identity      Obs per group: min =         1
Family:                           Gaussian                     avg =       2.8
Correlation:                  exchangeable                     max =         6
                                                Wald chi2(8)       =     18.29
Scale parameter:                  76.27317      Prob > chi2        =    0.0192

------------------------------------------------------------------------------------
          rf_g |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------+--------------------------------------------------------------------
    stades_bin |
          4-5  |  -6.198667   7.981792    -0.78   0.437    -21.84269    9.445359
       temps_m |   .0126925   .0437215     0.29   0.772        -.073    .0983851
stadebin_temps |   .0364772   .0571538     0.64   0.523    -.0755422    .1484966
         age_y |   2.059512   .9296017     2.22   0.027     .2375257    3.881497
         fille |   4.117839   8.432864     0.49   0.625    -12.41027    20.64595
          chir |    16.4003   8.273617     1.98   0.047     .1843125     32.6163
    autresdiag |   25.49619   11.17688     2.28   0.023     3.589904    47.40248
         compl |  -10.62481   6.408625    -1.66   0.097    -23.18549    1.935861
         _cons |   20.17739   16.85364     1.20   0.231    -12.85515    53.20992
------------------------------------------------------------------------------------
```

Red : Left renal function increased by 16.4% in right kidney injury, after surgical treatment. (95% CI, 0.18-32.6, p=0.047). Green : Left renal function increased by 25.6%, with congenital anomlities (95% CI, 3.6-47.4, p=0.023).

Table 5:

```
. xtgee ia_g i.stades_bin temps_m stadebin_temps age fille chir autresdiag compl if
rein ==1, family(gaussian) nolog

GEE population-averaged model                   Number of obs      =        28
Group variable:                        ipp      Number of groups   =        10
Link:                             identity      Obs per group: min =         1
Family:                           Gaussian                     avg =       2.8
Correlation:                  exchangeable                     max =         6
                                                Wald chi2(8)       =    102.47
Scale parameter:                  1.304505      Prob > chi2        =    0.0000

--------------------------------------------------------------------------------
          ia_g |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
    stades_bin |
          4-5  |  -2.853704    .877224    -3.25   0.001    -4.573032   -1.134377
       temps_m |   .0139961   .0100612     1.39   0.164    -.0057235    .0337157
stadebin_temps |  -.0182028   .0136499    -1.33   0.182    -.0449561    .0085505
         age_y |    .461967   .0797347     5.79   0.000     .3056899    .6182441
         fille |  -.4386092   .7631828    -0.57   0.565     -1.93442    1.057202
          chir |   5.545472   .8281328     6.70   0.000     3.922362    7.168583
    autresdiag |   7.080037   .9540392     7.42   0.000     5.210155     8.94992
         compl |   -.152673    .616889    -0.25   0.805    -1.361753    1.056407
         _cons |  -.1588989   1.575698    -0.10   0.920    -3.247211    2.929413
```

Red: Left accumulation index increased by 5.5% in right kidney injury following surgical management (95% CI, 3.9-7.2, p<0.05). *Green* : Left accumulation increased by 7.1% in right kidney injury, with congenital anomalies (95% CI, 5.2-8.9, p<0.05).

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