Abstract

Introduction: Acute kidney injury as defined by RIFLE (Risk, Injury, Failure, Loss, End-stage) and AKIN (Acute Kidney Injury Network) criteria is a common complication after major surgery and occurs in 36% of patients admitted to intensive care. The importance of early diagnosis of acute renal injury comes from the fact that renal injury may progress to renal failure, increasing in-hospital mortality and costs despite new treatment or prevention methods. Robotic surgery is the latest minimally invasive surgical method with many advantages. The main disadvantage is its high cost.

The aim of this study was to evaluate renal function by analysis of changes in serum creatinine, in robotic assisted laparoscopic surgery under general anaesthesia.

Materials and methods: We performed a descriptive, observational prospective longitudinal study, which were scheduled for robot-assisted laparoscopic surgery. Acute kidney injury was defined as absolute increase in serum creatinine of 0.3 mg/dl, in accordance with AKIN criteria. 23 male patients scheduled for robotic urogenital interventions, with a mean age of 59 years were included in the study. Surgical interventions performed were: 18 prostatectomies, 3 partial nephrectomies, 1 pieloplasty and 1 cystectomy. The average duration of surgery was 5.23 hours.

Results: Nine patients (representing 39%) developed acute kidney injury; defined as ≥0.3 mg/dl (27 μmol/l) increase of serum creatinine, renal function, was assessed by repeated measurements of serum creatinine. AKI (acute kidney injury), defined as an absolute increase of serum creatinine of 0.3 mg/dl (26.4 μmol/l) compared to baseline values, 72 hours after surgery, was transient. Serum creatinine on the 4th postoperative day was comparable to baseline levels.

Conclusions: Robotic surgery changes renal function by decreasing renal perfusion due to special circumstances, such as pneumoperitoneum, Trendelenburg position and fluid restriction in prostate surgery. Acute kidney injury is transient in robotic surgery performed under general anaesthesia, and resolves within four days postoperatively.

Keywords: acute kidney injury (AKI), robotic surgery, general anaesthesia, uro-genital organ perfusion, creatinine

Introduction

Acute kidney injury (AKI) is the consensus term used to describe the condition previously known as
Acute renal failure. AKI, as defined by RIFLE (Risk, Injury, Failure, Loss of function, End-stage) and AKIN (Acute Kidney Injury Network) criteria includes the full spectrum of changes in renal function, while renal failure is considered to be the final stage of AKI. Reducing peri-operative perfusion of urogenital organs increases the risk of ischemia, necrosis and infection. Quite frequently, diagnosis is delayed and is associated with increased morbidity and mortality, which involves prolonged hospitalization, increased costs, and loss of quality of life to the patients affected.

AKI occurs in 36% of patients admitted to the ICU [1] and is a common complication after major cardiovascular surgery [2]. It increases in-hospital mortality and costs in spite of new treatment and intervention methods.

In an effort to reach a consensus on the classification of acute kidney injury, ADQI (Acute Dialysis Quality Initiative Group) developed the RIFLE [3] criteria in 2004, establishing three severity classes: R (risk), I (injury), F (failure) and two outcome classes: L (loss of function), E (End Stage Renal Disease), as shown in Table I.

RIFLE criteria are of clinical importance for diagnosis [4], classification of severity [5], monitoring of AKI progression [6], and for prognosis [7].

For further refinement of the definition of AKI, AKIN [8] (Acute Kidney Injury Network) Table II, proposed new RIFLE criteria in 2007. They establish three stages, consistent with the RIFLE criteria. Stage 1 – Risk, stage 2 – Injury, stage 3 – Failure, Loss and End Stage were considered prognostic factors.

The Da Vinci robotic surgical system, the most advanced robot used in clinical practice, allows a minimally invasive approach and is ideal for urologic surgery [9,10]. The system consists of an ergonomic surgeon console, a patient cart with four interactive robotic arms, a 3D high resolution visualization interface and specific EndoWrist [11] articulated tools. This system is designed to transform, filter and transmit the surgeon’s hand movements into precise movements of the instruments, and is an intuitive interface with high performance surgical skills [12] used in urology, general surgery, gynaecology and thoracic surgery [13].

The advantages [14] of this surgical technique are: reduced bleeding, 3D visualization, superior image

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**Table I. Risk, Injury, Failure, Loss of function, End Stage Renal Disease, (RIFLE) classification**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Glomerular filtration criteria</th>
<th>Diuresis criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk</td>
<td>Serum creatinine increases by 1.5 fold, GFR* decreases &gt;25%</td>
<td>&lt;0.5 ml/kg/h over 6 hrs</td>
</tr>
<tr>
<td>Injury</td>
<td>Serum creatinine increases by 2 fold, GFR decreases &gt;50%</td>
<td>&lt;0.5 ml/kg/h over 12 hrs</td>
</tr>
<tr>
<td>Failure</td>
<td>Serum creatinine increases by 3 fold, or creatinine ≥4 mg/dl, or acute increase of creatinine &gt;0.5 mg/dl, or GFR decreases &gt;75%</td>
<td>&lt;0.3 ml/kg/h over 24 hrs or anuria over 12 hours</td>
</tr>
<tr>
<td>Loss</td>
<td>Persistent loss of kidney function &gt;4 weeks</td>
<td></td>
</tr>
<tr>
<td>ESRD</td>
<td>End Stage Renal Disease &gt;3 months</td>
<td></td>
</tr>
</tbody>
</table>

* GFR = glomerular filtration rate

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**Table II. Acute Kidney Injury Network (AKIN) classification**

<table>
<thead>
<tr>
<th>AKIN stage</th>
<th>Serum creatinine</th>
<th>Diuresis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>increases 1.5-2 fold, or by 0.3 mg/dl (27 μmol/l)</td>
<td>&lt;0.5 ml/kg/h over 6 hrs</td>
</tr>
<tr>
<td>2</td>
<td>increases 2-3 fold</td>
<td>&lt;0.5 ml/kg/h over 12 hrs</td>
</tr>
<tr>
<td>3</td>
<td>increases &gt; 3 fold, or &gt;4 mg/dl (354 μmol/l), with an acute increase by &gt;0.5 mg/dl (44μmol/l)</td>
<td>&lt;0.3 ml/kg/h over 24 hrs, or anuria over 12 hours</td>
</tr>
</tbody>
</table>
quality and EndoWrist instruments with seven degrees of free movement, allowing complex movements in small spaces, reduced postoperative pain, rapid resumption of intestinal transit, reduced complications, smaller scars, reduced hospitalization combined with quick recovery, and nerve sparing, which improves urinary continence and sexual dynamics. The main disadvantage is the high cost [15] of this method, as it increases overall costs by approximately $200, or 20% of global prostatectomy costs [16,17].

The aim of this study was to evaluate renal function in robot-assisted laparoscopic surgery performed under general anaesthesia, by means of repeated serum creatinine measurements.

**Materials and Methods**

We performed a descriptive, observational prospective longitudinal study, including 23 patients admitted to the Urology Department of Cluj-Napoca Municipal Hospital between May 2010 and February 2012, who were scheduled for robot-assisted laparoscopic surgery.

The patients included were scheduled for urological robot-assisted laparoscopic surgery, with no history of chronic renal disease (RIFLE classification R at most), classified as AKIN [18] stage 1, with stable hemodynamic and breathing.

The study was approved by the Ethics Committee of the Cluj-Napoca Municipal Hospital. All patients included agreed to participate after being duly informed on the implications of their inclusion in the study, and signed an informed consent form. Patients were informed of the type of surgery and anaesthesia they were to receive.

From all patients included the following data were collected: pre-operatively – demographic data (gender, age), comorbidity score (Charlson Comorbidity Index [19], physiological scores (Apache II [20], SOFA [21]), risk of anaesthesia assessed by ASA [22] score. Renal function was assessed by RIFLE and AKIN criteria; during surgery: duration of intervention measured in hours (h), haemorrhage (ml), cardiovascular (average BP over 60 mm Hg) and respiratory (peripheral blood oxygen saturation of 94%) stability. Postoperatively we followed vital signs (BP pulse, respiration), daily diuresis over 4 days postoperatively, and serum creatinine was sampled daily over the first 4 days postoperatively. Renal function was assessed by analysis of changes in serum creatinine.

Acute kidney injury (AKI) was defined by absolute increase in serum creatinine of 0.3 mg/dl (26.4 μmol/l) compared to baseline levels within 72 hours after surgery, in accordance with new AKIN criteria.

**Statistical analysis**

Qualitative variables were expressed as a percentage, with a confidence interval of 95% (CI 95%) computed for each percentile, using a method optimized method similar to that presented in the article [23].

Quantitative variables were summarized by arithmetic mean and standard deviation (mean standard deviation) for variables with a normal distribution, and as median plus 25% and 75% quartiles for variables that do not follow a normal distribution. The Kolmogorov-Smirnov test [24,25] was used to assess normality; a probability of less than 5% associated with the Kolmogorov-Smirnov statistic indicated the absence of normal data distribution. The Friedman test was used to identify statistically significant differences between baseline serum creatinine values sampled on day 1, day 2, day 3 and day 4 postoperatively. The aim was to follow the changes in renal function, defined as AKI occurrence robot-assisted laparoscopic surgery performed under general anaesthesia.

**Results**

Twenty-three patients met the study inclusion criteria and their renal function was assessed against serum creatinine levels. Patients were all male, aged between 22 and 72 years, with a mean age of 59 years (median age = 62 years, 25% percentile = 56 years and 75% percentile = 65 years). Most patients were undergoing prostatectomy (18 patients, 78% CI 95% [57%-91%]). Three patients underwent partial nephrectomies (13%, CI 95% [5%-35%]) and one patient underwent cystectomy and pieoplasty, respectively.

The comorbidity score was between 0 and 10, with a median of 3 (percentile 25% = 2, percentile 75% = 5). Apache score was between 1 and 10, with a median of 6 (25% percentile = 4, 75% percentile = 8). Four patients (17%, CI 95% [5%-39%]) had a SOFA score of 1.

The average duration of surgery was 5.23±1.01 hours, and ranged between 4 and 7 hours. Bleeding volume ranged between 200 and 400 ml, with a median of 250 ml and percentiles values of 25% and 75% of 200 ml and 300 ml, respectively.

Concerning serum creatinine levels, only the baseline and 4th post-op samplings were found to have a normal distribution. A summary of creatinine values is shown in Table III, and the evolution of serum creatinine values per patient is presented in Figure 1.

Applying the Friedman test we identified a significant difference in serum creatinine values.
investigated (chi-squared test value=19.956, degrees of freedom=4, associated probability test p=0.001). The average basal creatinine proved to differ insignificantly from average serum creatinine levels determined on day 4 postoperatively (t statistic=0.705, 22 degrees of freedom, p=0.488). The results of differences between baseline serum creatinine levels and those measured on different days postoperatively are shown in Table IV.

Nine cases developed acute kidney injury, defined as absolute growth of serum creatinine of 0.3 mg/dl above baseline within 72 hours of surgery (39%, CI95% [18%-61%]). However, this criterion was not maintained on post-op day four.

Discussion

The incidence of this type of renal injury consecutive to robot-assisted laparoscopic surgery has not yet been studied. Some specific features of robot-assisted laparoscopic surgical procedures (pneumoperitoneum, Trendelenburg position and hydration restriction in prostatectomies) reduce splanchnic perfusion and increase the incidence of AKI.

The incidence of AKI in robotic surgery was 39%. In literature AKI is described to occur in 36% of patients admitted to intensive care units [2], in 33.5% of patients undergoing bone marrow transplantation [26], 35.7% in patients with burns [27], 35.9% in liver transplant recipients [28] and 37.4% in septic patients [29].

This is the first study that monitors renal function in robotic surgery performed under general anaesthesia, by means of changes in the levels of serum creatinine. Using implemented statistical methods, it provides evidence that AKI occurs in robot-assisted surgery performed under general anaesthesia, but it also reveals that changes to the renal function are transient.

In the USA, 42% of radical prostatectomies performed in 2006 were done using the robot approach; in 2007 their proportion increased to 60% [30]. Currently, 72% of radical prostatectomies performed in the U.S. are done using Da Vinci robotic surgery and the percentage is growing.

Limitation of the study consisted in the use of serum creatinine to define occurrence of AKI. Proteomic methods were used to identify new serum and urine biomarkers, which promise to provide a prompter
diagnosis of acute kidney injury. These biomolecules are not yet included in current diagnostic criteria.

Conclusions

Renal function changes in robotic surgery, with a statistically significant difference between serum creatinine on postoperative day 1 and baseline levels ($p<0.005$).

In most cases (7 out of 9; 77%), peak serum creatinine levels were recorded on first postoperative day; in other cases the peak value was recorded on day 2 after surgery.

There is statistically significant difference ($p<0.002$) between serum creatinine values on days 2, 3, and 4 after surgery, compared with those on postoperative day 1, with a pattern of gradual decrease close to baseline levels on postoperative day 4.

AKI appears in robotic surgery, with incidence rates comparable to those known from other major surgical procedures quoted in literature. Renal dysfunction is transient; there is no statistically significant difference between serum creatinine levels on the fourth day after surgery and baseline samples, respectively.

References


Translation: Dr. Peter László-Herbert