Positioning Injuries Associated with Robotic Assisted Urological Surgery

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Abbreviations and Acronyms
BMI = body mass index
IV = intravenous

Purpose: Nerve injury associated with patient positioning during surgery is well documented. With the development of robotic surgery, surgeons are faced with new surgical positioning, requiring attention to ensure patient safety. Published reports that address positioning injury during robotic surgery are sparse and none address the overall incidence. In this study we determine the incidence of positioning injury during robotic assisted urological surgery, identify risk factors and describe the time to resolution of the neurological injury.

Materials and Methods: We reviewed all adult urological cases at our institution that used the da Vinci® Si and da Vinci Standard® Surgical System from January 2010 to December 2011. We characterized risk factors into the 4 domains of positioning, operative, patient specific and anesthesia related. Within these 4 categories we collected data on 13 specific aspects of patient care to determine their association with positioning injury.

Results: Of 334 operations 22 positioning injuries (6.6%) were documented. Of these injuries 13 (59.1%) resolved within 1 month, 4 (18.2%) resolved between 1 and 6 months, and 5 (22.7%) persisted beyond 6 months. We found operative time (p <0.0001), in-room time (p <0.0001) and ASA (American Society of Anesthesiologists) class (p = 0.0033) were significantly associated with injury.

Conclusions: Positioning injuries are under recognized in robotic assisted urological surgery and may persist beyond 6 months. Consideration must be given to counseling patients about the risks of positioning injuries, especially for long operations. Patients with multiple medical comorbidities (ASA class 4) are particularly at risk for these injuries.

Key Words: robotics; patient positioning; trauma, nervous system; complications; urogenital system

Nerve injury associated with patient positioning during surgery is well documented. Mild compression of a nerve may lead to temporary disruption of conduction that is reversible with reperfusion, while more severe compression or stretching of a nerve may lead to endoneurial edema, demyelination or wallerian degeneration. The most severe compression results in degenerated axons and the time required to recover from these injuries varies depending on the length of the degenerated axons. In the most extreme cases recovery may not be possible. The incidence of peripheral nerve complications has been cited as 0.14% in open general surgery and 0.3% in open retropubic radical prostatectomy. However, postoperative neuropathy accounted for 16% of com-
plaints from the Closed Claims Project, an analysis of 4,000 anesthesia related insurance claims for all types of surgery, suggesting underestimation of the true incidence. The incidence of neuromuscular injury during laparoscopic urological procedures has been cited as 2.7%. Factors contributing to positioning injury have been categorized as patient related or operative related. Patient related factors include BMI, variant anatomy, and comorbidities such as diabetes mellitus and vascular disease. Operative related factors include physical position on the operating room table and operative duration. With the development of robotic surgery, surgeons are faced with new surgical positioning, requiring attention to ensure patient safety. Robotic assisted surgery is different from laparoscopic surgery in that it often uses more equipment and a steeper Trendelenburg position. An association between lower extremity injury and operative time when using split-leg positioning during robotic surgery has been reported. Increased injury may be partially due to the robotic arms obscuring the surgeon's view of the patients, placing patients at risk for positioning injuries from slippage or from unrecognized compression from the robotic arms.

At our institution the da Vinci Surgical System was first used to perform minimally invasive prostatectomy in 2004, partial nephrectomy in 2007 and cystectomy in 2009. As we moved beyond robotic assisted radical prostatectomy, we noted several patients had ulnar nerve palsies and we developed an increased awareness of this complication. A review of the literature suggested that the incidence of short and long-term neuropathic injury during robotic assisted surgery is not known. Therefore, we determined the incidence of positioning injury during robotic assisted urological surgery, identified risk factors and described the time to resolution of the neurological injury.

MATERIALS AND METHODS

Under an institutional review board approved retrospective review protocol, we performed chart abstraction on all adult urological cases using the da Vinci Si and da Vinci Standard Surgical System from January 1, 2010 to December 31, 2011.

Risk Factors

We characterized risk factors into 4 overarching domains of positioning, operative, patient specific and anesthesia related. Within these 4 categories we collected data on 16 specific aspects of patient care to determine their association with positioning injury (supplementary Appendix 1, http://jurology.com/). The positioning and operative factors were collected from nursing notes created from a detailed uniform checklist of positioning and safety checks. The factors included the exact positioning of the upper extremities in an abducted, adducted or across the chest position; the laterality of the operation; use of a bean bag positioning device to hold the patient in a certain position; the location of tape or straps across the patient; the degree of Trendelenburg tilt of the operating table; the time from incision to closure (case time); and the total time that the patient was in the operating room (in-room time). Patient specific and anesthesia related factors were documented using preoperative history and physical examination as well as the anesthesia operative log, and included patient BMI, history of neurological and vascular comorbidities, history of diabetes mellitus, patient ASA physical status classification (ASA class), total IV fluids administered during the operation, the neuromuscular agent used, and the frequency of checks on the positioning and safety of the patient during the operation. After performing an interim analysis of the 2010 urological surgery data, the scope of the factors analyzed was narrowed to exclude the neuromuscular agent, frequency of positioning checks and patient gender. Thus, the final analysis included 13 factors.

Outcomes

The primary outcome of interest was defined as the incidence of positioning injury in an upper or lower extremity. Positioning injury was defined as weakness, paresthesia, numbness, or any other peripheral neurological or muscular complaint. Each patient chart was carefully reviewed for documentation of any new complaint from the Post-Anesthesia Care Unit record to the last follow-up visit. Although this was a retrospective study, the urology team likely had an increased awareness of injury during this time due to a previously noted injury. The secondary outcomes of time to resolution of the injury and management required were also recorded.

Statistical Analysis

Descriptive statistics initially compared the positioning injury cohort with the controls. The chi-square test was used to determine significant differences. All analyses were performed with SAS® 9.2. Multivariate analyses were conducted. Logistic regression with the Firth method was used to assess the effects of case time and IV fluids on the odds of an injury. The results of Vittinghoff and McCulloch suggest that 5 to 9 events per predictor are adequate for this type of model

RESULTS

Incidence of Neuropathic Injury

During the 2-year period we performed 334 diverse robotic assisted adult urological procedures including prostate, renal, adrenal and bladder procedures. The incidence of injury by robotic assisted urological procedure is shown in table 1. A total of 22 (6.6%) positioning injuries were documented. Retropertioneal lymph node dissection had the highest percentage of patients with injuries, with 4 of 10 (40%) experiencing a positioning injury. Adrenalectomy had the second highest percentage of patients with injuries, with 1 of 6 (17%) experiencing a positioning injury. The most frequently performed operations,
radical prostatectomy and partial nephrectomy, each had an injury incidence of 7%.

**Overview of Factors Associated with Injury**

Case time (p < 0.0001), in-room time (p < 0.0001), ASA class (p = 0.0033) and amount of IV fluids infused (p = 0.004) were significantly associated with injury. Upper extremity positioning approached statistical significance (p = 0.054). Table 2 presents the factors associated and not associated with injury.

**Detailed Analysis of Factors Associated with Injury**

**Operative and anesthesia related factors.** Median case time was 328 minutes for cases which resulted in positioning injury and 240 minutes for those which did not result in positioning injury (p < 0.0001). The quartiles of case time for the injured and uninjured groups are shown in the figure. Median IV fluids administered during cases were 3,200 ml for those which resulted in positioning injury and 2,509 ml for those which did not result in positioning injury (p = 0.004).

**Patient specific factors.** None of 22 cases with an ASA class of 1 resulted in positioning injury. With an ASA class of 2, 14 of 222 (6.3%) cases resulted in positioning injury. With an ASA class of 3, 6 of 86 (7.0%) cases resulted in positioning injury and with an ASA class of 4, 2 of 4 (50.0%) resulted in positioning injury (p = 0.0033).

**Upper extremity positioning.** When positioning the patient with upper extremities tucked or at the side, 7 of 183 (3.8%) patients experienced an injury. Positioning one upper extremity out on an arm board with the contralateral upper extremity tucked or at the side resulted in injury in 14 of 130 (10.8%) cases. With both upper extremities out on an arm board, injury occurred in 1 of 6 (14.3%) cases. No injuries occurred in 14 cases positioning one upper extremity across the chest and one extremity out on an arm board (p = 0.054, not statistically significant).

Of the 13 of 22 (59%) injuries that involved upper extremity injury, 8 of 13 (62%) were unilateral where the injured upper extremity was tucked or at the side, and 1 of 13 (8%) was unilateral where the upper extremity was abducted onto an arm board. Of the 13 upper extremity injuries 4 affected the patient bilaterally, and 2 of 13 (15%) had 1 extremity tucked and 1 abducted, 1 of 13 (8%) had both extremities abducted, and 1 of 13 (8%) had both extremities tucked or at the side. Overall of the 13 patients with an upper extremity injury 11 (84%) had at least 1 injured upper extremity that was tucked or at the side.

**Table 1. Association of specific operations with injury**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>No. Procedures Performed</th>
<th>No. Neuropraxic Injury (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prostatectomy</td>
<td>137</td>
<td>10 (7.30)</td>
</tr>
<tr>
<td>Partial nephrectomy</td>
<td>56</td>
<td>4 (8.50)</td>
</tr>
<tr>
<td>Pyeloplasty</td>
<td>61</td>
<td>1 (1.64)</td>
</tr>
<tr>
<td>Cystectomy</td>
<td>24</td>
<td>2 (8.83)</td>
</tr>
<tr>
<td>Nephroureterectomy</td>
<td>14</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Ureteral reimplantation</td>
<td>11</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Retroperitoneal dissection</td>
<td>10</td>
<td>4 (40.0)</td>
</tr>
<tr>
<td>Radical nephrectomy</td>
<td>7</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Adrenalectomy</td>
<td>6</td>
<td>1 (16.7)</td>
</tr>
<tr>
<td>Ureterostomy</td>
<td>3</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Appendicovesicocystotomy</td>
<td>2</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Bladder diverticulectomy</td>
<td>1</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

**Table 2. Association of factors with injury**

<table>
<thead>
<tr>
<th>Associated with Injury</th>
<th>p Value</th>
<th>Not Associated with Injury</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case time</td>
<td>&lt;0.001</td>
<td>Upper extremity positioning</td>
<td>0.054</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laterality of operation</td>
<td>0.610</td>
</tr>
<tr>
<td>In-room time</td>
<td>&lt;0.0001</td>
<td>Use of bean bag positioner</td>
<td>0.0610</td>
</tr>
<tr>
<td>ASA class</td>
<td>0.0033</td>
<td>Position of tape or straps</td>
<td>0.391</td>
</tr>
<tr>
<td>IV fluids administered</td>
<td>0.004*</td>
<td>Table tilt</td>
<td>0.300</td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td></td>
<td>0.178</td>
</tr>
<tr>
<td>Neurological comorbidities</td>
<td></td>
<td></td>
<td>0.416</td>
</tr>
<tr>
<td>Vascular disease</td>
<td></td>
<td></td>
<td>0.949</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td></td>
<td></td>
<td>0.730</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td>0.840</td>
</tr>
<tr>
<td>Neuromuscular agent</td>
<td></td>
<td></td>
<td>0.389</td>
</tr>
<tr>
<td>Positioning check</td>
<td></td>
<td></td>
<td>0.374</td>
</tr>
</tbody>
</table>

* Associated with case time in multivariate analysis.

† Data from 2010 interim analysis only.
Duration of Injury
Thirteen (59.1%) injuries resolved within 1 month, 4 (18.2%) resolved between 1 and 6 months, and 5 (22.7%) persisted beyond 6 months despite neurology, physical therapy and occupational therapy consultation.

Multivariate Analysis
To assess the contribution of IV fluid and case time to injury, we performed bivariate analysis. IV fluids were not significantly associated with injury once there was adjustment for case time (p = 0.27).

DISCUSSION
Our study revealed a 6.6% incidence of positioning injury associated with robotic assisted urological surgery and 23% of these injuries persisted beyond 6 months. Each injury is presented fully in supplementary Appendix 2 (http://urology.com/). Functional limitations included hand and foot numbness, radial and median nerve palsy, and hip adduction and flexion weakness. Details of positioning for robotic assisted procedures at our institution are also included in supplementary Appendix 2.

Some readers may be surprised by these findings and dismiss them as not applicable to their patient population. Our incidence rate is most likely higher than anticipated because of our increased awareness of injury. Nonetheless, this was not a prospective study and if postoperative sensory and motor function were measured, it is conceivable that this retrospective study underestimated the true incidence of positioning injury.

Interestingly as we expanded our repertoire of robotic assisted surgeries to adenectomy and retroperitoneal lymph node dissection, we noted an increase in injuries. The reason for this increase is twofold. 1) The sample size is small for these less frequently performed procedures, artificially inflating the proportion of injuries. 2) There may be a learning curve for surgeons, operating room staff and anesthesiologists for positioning and fluid management in new robotic procedures.

Our research suggests methods to minimize the risk of positioning injuries. Increased operative time was significantly associated with injury, which makes sense given that the severity of nerve injury is related to the duration of nerve compression. Median case time was 5.5 hours for cases which resulted in positioning injury and 4.0 hours for those which did not result in positioning injury (p <0.0001). Interestingly there is minimal overlap in the middle 2 quartiles of case time for these 2 groups (see figure). This evidence is not sufficiently strong to support a cutoff or target time for these operations. However, this information may be useful for intraoperative decision making, particularly in cases that exceed 5 hours. For cases with a longer duration, frequently checking patient positioning and taking patients out of the lithotomy position after undocking the robot are advisable. The creation of a positioning checklist for each position or operation may be prudent.

Patients at greatest risk for injury are those with a higher ASA class. Normal healthy patients (ASA class 1) did not experience any injuries, whereas patients with mild systemic illness (ASA class 2) and severe systemic illness (ASA class 3) were injured at rates of 6.3% and 7.0%, respectively. The incidence of injury increased dramatically to 50% in patients with severe systemic illness that was a constant threat to life (ASA class 4). However, only 4 patients had this classification. It is important to note that no specific disease process was found to be associated with injury, including neurological comorbidities, vascular comorbidities and diabetes mellitus. Optimal patient selection and preoperative management may be key strategies to mitigate the risk of numerous complications including positioning injuries.

Association of upper extremity positioning with injury did not reach statistical significance (p = 0.054). However, we consider this an important issue. Although the highest proportion of injury occurred when one upper extremity was abducted and the other was tucked, most of these injuries occurred in the tucked extremity. In fact, of the 13 patients with an upper extremity injury 11 (84%) had at least one injured upper extremity that was tucked or at the side. This may result from stretch or pressure on the brachial plexus or increased compression of more distal nerves while the extremity is tucked.

Increased IV fluids (mostly crystalloid) were significantly associated with increased positioning injuries. However, on multivariate analysis this was determined to be due to the association between IV fluids and operative time.

Surgeons debate whether the use of a bean bag positioning device in robotic assisted surgery increases or decreases the risk of nerve injury. In this study the bean bag device was used in 33% of operations. We used the bean bag 60 times in 2010, with 6 positioning injuries when the device was used. In 2011 we used it 51 times and recorded only 1 positioning injury when using the device. We performed an interim analysis of the 2010 data, so it is possible that we used the bean bag more appropriately in 2011. Overall, bean bag use was not associated with injuries (p = 0.061). Future prospective studies may focus on the use of the bean bag device and the appropriate selection of positions or operations for the device. At our institution the bean bag positioning device is no longer used. The broader issue of the patient slipping from original positioning is impor-
tant for all health care providers including patient care assistants, operating room nurses and residents in training to recognize as the consequences may be long-lasting.

CONCLUSIONS
Positioning injuries are under recognized in robotic assisted surgery. Consideration must be given to counseling patients about the risks of positioning injuries, especially with long operations. Of these injuries 23% may persist for more than 6 months and some may lead to permanent disabilities. Patients with multiple medical comorbidities (ASA class 4) are particularly at risk for these injuries. Careful counseling and offering more conservative options may be prudent in this population.

REFERENCES