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ORIGINAL ARTICLE

Changes in airway dimensions after robot assisted surgeries in steep Trendelenburg position

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Abstract

Robotic surgeries in the extreme Trendelenburg position can lead to changes in the airway dimensions. We conducted a prospective, observational trial to explore the use of ultrasound to quantify these changes in the airway dimensions and identify the factors associated with it. Fifty-two American society of Anaesthesiologists physical status I–II patients between 18 and 70 years of age of either sex scheduled to undergo robot assisted urological procedures in steep Trendelenburg position were enrolled. Anterior soft tissue thickness at the level of hyoid bone and vocal cords, tongue thickness, Malampatti grading and neck circumference were measured at predefined postoperative intervals in the immediate postoperative period, at 2-, 6- and 12-h period postoperatively. Linear stepwise regression analysis was done to explore the factors associated with change in anterior tissue thickness immediately after surgery. The mean difference (95%; CI) in the anterior soft tissue thickness in the immediate postoperative period at the level of hyoid was 0.023 (0.029–0.016) cm, $p < 0.001$ and at level of vocal cords was − 0.012 (− 0.017 to − 0.008) cm, $p < 0.001$ from the baseline. There was a significant increase in tongue thickness (0.002), Mallampati score ($p = 0.002$) and neck circumference ($p < 0.001$) in immediate postoperative period. The change in anterior tissue thickness at the level of hyoid was affected by total intraoperative fluids used ($r = 0.602$, $p < 0.001$), airway trauma ($r = 0.275$, $p = 0.002$) and duration of surgery ($r = 0.243$, $p = 0.025$). Significant changes in airway dimensions after robotic surgeries in Trendelenburg position persist till 2 h in the postoperative period which warrant vigilant monitoring for any airway compromise during this period.

Keywords Airway assessment · Ultrasonography · Upper airway anatomy · Head down position.

Introduction

Robot assisted urological procedures, especially radical retropubic prostatectomy (RARRP), robot assisted laparoscopic radical cystectomy (RALRC) and robot assisted vesico vaginal fistula (VVF) repair demand extreme Trendelenburg position of 24°–45° [1]. This unphysiological position has been reported to be associated with adverse events

Preliminary data for this study were presented at 64th National Conference of Indian Society of Anaesthesiology at Ludhiana from 25th to 30th November, 2016 and was awarded second prize in oral paper presentation.

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like postoperative airway compromise, decreased pulmonary compliance, corneal abrasions and brachial plexus injuries [2–4].

Airway compromise in the postoperative period is one of the biggest threats in patients undergoing surgery in extreme trendelenburg position which can warrant placement of tracheal tube in a critical situation in the postoperative period [5]. Attempts at re-securing the airway may pose difficulty due to change in airway dimensions. The fourth National Audit Project (NAP 4) conducted by the Royal college of Anaesthesiologists and Difficult Airway Society reported three cases of airway catastrophes in the postoperative period following robotic surgery in steep trendelenburg position [6].

To understand the airway anatomy and changes if any, current literature suggests the use of sonography as a simple, non invasive bedside tool. Studies focussed on airway changes during surgery have commented on the usefulness of ultrasonography for better airway-related management [7–9]. In order to study airway changes associated with steep trendelenburg position we proposed a prospective observational trial that aimed to explore the use of bedside ultrasound to quantify the changes in the airway dimensions in robotic surgeries demanding steep trendelenburg position. As exploratory measures we also wished to evaluate these changes at different predefined intervals postoperatively and factors affecting these changes.

Methods

The present prospective, observational study was conducted in the robotic unit of the tertiary care hospital, after being approved by Institute's Ethics Committee and obtaining written informed consent from the patients. Fifty-two American society of Anaesthesiologists physical status I–II patients between 18 and 70 years of age of either sex scheduled to undergo robot assisted urological procedures demanding trendelenburg position were enrolled for this trial. Patients having upper airway pathology, cervical spine fractures, mallampati grade 4, history of difficult laryngoscopy or intubation, heart failure, renal disease or those who required postoperative mechanical ventilation were excluded from the trial.

All the patients were kept fasting for 8 h for solid food and 2 h for clear liquids as per standard NPO protocol. First series of objective airway assessment including the Mallampati grading (MMG), thyromental distance (TMD), neck circumference (NC) and airway sonography to measure the tongue thickness and anterior soft tissue thickness (ASNT) at the level of hyoid and vocal cord was performed just before induction of anaesthesia in the operating room.

A standardised anaesthesia technique was followed in all the patients and routine monitors like electrocardiogram (ECG), non invasive blood pressure (NIBP) and pulse oximeter were attached. General anaesthesia was induced using propofol 2 mg kg^{-1} and vecuronium 0.1 mg kg^{-1} for muscle relaxation to facilitate endotracheal intubation. Morphine 0.1 mg kg^{-1} was administered for intraoperative analgesia. Anaesthesia was maintained by isoflurane 1–1.5% (target MAC of 1.2) with N_2O in oxygen (FiO_2 0.4%). Patients were mechanically ventilated with 6–8 ml kg^{-1} tidal volume and postive end expiratory pressure (PEEP) of 5 to maintain end tidal CO_2 ($ETCO_2$) at 35–40 mmHg (Datex Ohmeda S5 Avance work station). Ringer lactate (RL) at 4–6 ml kg^{-1} h^{-1} was given as maintenance fluid. The endotracheal tube cuff pressure was checked at regular intervals to ensure pressures < 30 cm H_2O. The surgical table was kept at 30° steep Trendelenberg position.

Tracheal intubation parameters including the number of attempts required for tracheal intubation, time taken for intubation and any airway trauma during intubation were recorded. Duration of surgery (from incision to application of bandage), duration of pneumoperitoneum and total volume of i.v. fluid administered during surgery were noted.

All patients were given inj. Diclofenac 75 mg i.v. for postoperative analgesia and ondansetron 4 mg i.v. as prophylactic antiemetic 30 min before emergence. At the end of anaesthesia, i.v. glycopyrollate 10 mcg kg^{-1} and neostigmine i.v. 50 mcg kg^{-1} were administered for reversal of residual neuromuscular blockade. Tracheal extubation was performed after performing the cuff leak test to rule out laryngeal oedema. Airway trauma at the time of extubation, postoperative dysphagia or hoarseness of voice if any was recorded.

The second series of airway assessment was performed in the recovery room after the patient attained the Aldrete score of > 9.

The primary outcome measured was ASNT at the level of hyoid in the immediate postoperative period. The secondary outcomes measured were ASNT at the level of vocal cords, tongue thickness, MMG, TMD, NC in the immediate postoperatively. These parameters were also recorded at 2, 6 and 12 h postoperatively as exploratory outcomes. Linear stepwise regression analysis was done to explore the factors associated with change in ASNT at the level of hyoid immediately after surgery.

Airway Ultrasound was performed by a single investigator having an experience of performing more than 20 airway ultrasounds. A curvilinear probe with 1–5 MHz frequency (Micro-Max SonoSite) was selected and placed in the submental region of the neck of the patient, in the midline in a sagittal plane. The anteroposterior thickness of the hypoechoic geniohyoid muscle of the tongue was measured. Thereafter, ASNT was measured from the skin

at two different levels in the axial plane using linear array probe (7–13 MHz), one at the level of hyoid bone and another at the level of vocal cords. At each level, three measurements (midline and approximately 10 mm to the left and right of the midline) were taken and averaged to obtain the soft tissue thickness.

Mallampati grading was assessed by Samsoon's and Young's [10] classification using digital camera Canon Powershot A550 by the anesthetist having more than 20 years of clinical anesthesia experience. A digital camera Canon power shot A550 was used to obtain an image of the airway with mouth as wide as permissible with maximal tongue protrusion without phonation. The images on the USB device were anonymised and annotated using a computer generated file number. A blinded anaesthetist assigned a class to each photograph.

NC was measured at the thyroid cartilage while TMD was measured with head extended.

Data analysis

Sample size collection was done based on the pilot study on ten patients. The ASTN at the level of hyoid was mean 6.1 cm with standard deviation of ± 0.12. Assuming an increase of 20% in the value of ASTN at the level of hyoid in the immediate postoperative period we got the sample size of 47 patients. To account for the attrition due to drop-outs, 52 patients were enrolled for the study with the alpha error of 0.5 and beta error of 0.02.

All calculations were performed using SPSS® version 20 (Statistical Packages for the Social Sciences, Chicago, IL).The quantitative data were presented as mean ± SD or median (95% CI), as appropriate. Qualitative or categorical data were described as frequencies and proportions.

Kolmogorov–Smirnov test was applied to judge the normal distribution of data. Wilcoxon's signed rank test was used to compare pre- and post anaesthetic values for individual airway assessments using conventional and ultrasound method. A p value of < 0.05 was considered to indicate statistical significance.

A forward stepwise regression model was used to find the factors affecting the ASNT at the level of hyoid. The variables of age, weight, height, BMI, intubation attempts, Airway trauma, duration of intubation, IV fluid intake, duration of surgery, duration of pneumoperitoneum and duration of laryngoscopy were used as potential predictors of the changes in airway changes (ASNT at hyoid) in the model building process. The entry and exit criteria were set at a significance level of 0.05 and 0.10, respectively. Coefficients of determination $(R)^2$ and adjusted R^2 were also calculated.

Table 1 Patient characteristics and intraoperative data of 52 patients in the study

Age, years	
Mean (SD)	54.6 (13.4)
Range	19–74
Height, cm	
Mean (SD)	167.4 (6.4)
Range	154–181
Weight, kg	
Mean (SD)	71.3 (8.5)
Range	52–81
Body mass index, kg/m^2	
Mean (SD)	25.7 (3.19)
Range	17.8–30.8
Gender (male/female)	39/13
ASA (1/2)	36/16
Diagnosis (ca. UB: ca. prostate: VVF)	22/18/12
Duration of pneumoperitoneum, min	
Mean (SD)	260.7 (150)
Range	65–575
IV fluids administered, ml	
Mean (SD)	1458 (538)
Range	600–2500

Table 2 Airway and intubation characteristics of 52 patients

MMP (1/2/3)	31:18:3
Snoring	8:44
No. of attempts for intubation, *n* (1/2)	42/10
Airway trauma during intubation, *n* (yes/no)	4/48
Duration of laryngoscopy, s	
Mean (SD)	20.6 (9.6)
Range	9–54
Post op hoarseness, *n* (yes/no)	7/45

Results

Out of 101 patients screened and assessed for eligibility. 35 patients did not meet exclusion criteria. Out of 66 patients found eligible, 12 refused to provide consent for surgery, and 2 were excluded due to violation of study protocol; thus 52 patients completed the trial and were analysed. The demographic and intraoperative data on airway parameters are summarised in Table 1, 2.

There was a significant increase in the mean value of ASTN at the level of hyoid in the immediate postoperative period ($p < 0.001$) and at 2 h postoperatively ($p < 0.001$) (Table 3). The mean difference (95% CI) in the ASNT at the level of hyoid was [− 0.023 (− 0.029 to 0.016) cm, $p < 0.001$] in the immediate postoperative period and [− 0.007 (− 0.011 to − 0.004) cm, $p < 0.001$] at 2 h postoperatively from the baseline value.

Table 3 Airway dimensions at predefined intervals in the postoperative period of 52 patients in the study

	*T*1	*T*2	*T*3	*T*4	*T*5
ASTN-H p-value	0.69 (0.68–0.71)	0.71 (0.69–0.74) <0.001	0.70 (0.68–0.72) <0.001	0.69 (0.68–0.71) 1.000	0.69 (0.68–0.71) 1.000
ASTN-VC	0.34 (0.32–0.35)	0.35 (0.34–0.37) <0.001	0.34 (0.32–0.35) 1.000	0.34 (0.32–0.35) 1.000	0.34 (0.32–0.35) 1.000
Tongue thickness	0.6 (0.59–0.62)	0.62 (0.60–0.63) <0.001	0.61 (0.59–0.62) 0.44	0.6 (0.59–0.62) 1.000	0.6 (0.59–0.62) 1.000
MMP (I/II/III/IV)	31/18/3/0	27/17/7/1 0.003	31/18/3/0 1.000	31/18/3/0 1.000	31/18/3/0 1.000
NC	35 (34.4–35.6)	35.4 (34.8–36) <0.001	35.1 (34.5–35.7) <0.001	35 (34.4–35.6) 1.000	35 (34.4–35.6) 1.000
TMD	66.15 (65.4–66.8)	66 (65.5–67) 0.014	66.15 (65.4–66.8) 1.000	66.15 (65.4–66.8) 1.000	66.15 (65.4–66.8) 1.000

Values are presented as median (95% CI) or absolute numbers

ASTN-H anterior soft tissue neck thickness at hyoid, *ASTN-VC* anterior soft tissue neck thickness at vocal cords, *MMP* modified Mallampati, *NC* neck circumference, *TMD* thyromental distance

Mean difference of ASNT (95% CI) at level of vocal cords showed significant change in the immediate post operative period −0.012 (− 0.017 to − 0.008) cm, $p<0.001$ from the baseline and returned to the baseline value within 2 h post operatively ($p=0.44$).

Significant change in tongue thickness was seen in the immediate postoperative period ($p = < 0.001$). There was an increase in the MMP ($p=0.003$) and NC ($p<0.001$) in immediate postoperative period which returned to baseline values at 2 h in postoperative period (Table 3).

Tracheal extubation was attempted in all the patients after the negative leak test. None of the patients were re-intubated in the postoperative period. 4 patients showed desaturation ($SpO_2<94\%$) in the immediate postoperative period, which was rectified after insertion of appropriately sized nasal airway.

The stepwise regression model showed strong association of ASTN at the level of hyoid with intraoperative fluids administered ($r=0.602$, $p<0.001$), airway trauma during intubation ($r=0.275$, $p=0.002$) and duration of surgery ($r=0.243$, $p=0.025$). A positive linear correlation of change in ASTN at the level of hyoid with the duration of surgery has been depicted through the slope of scatter plot (Fig. 1).

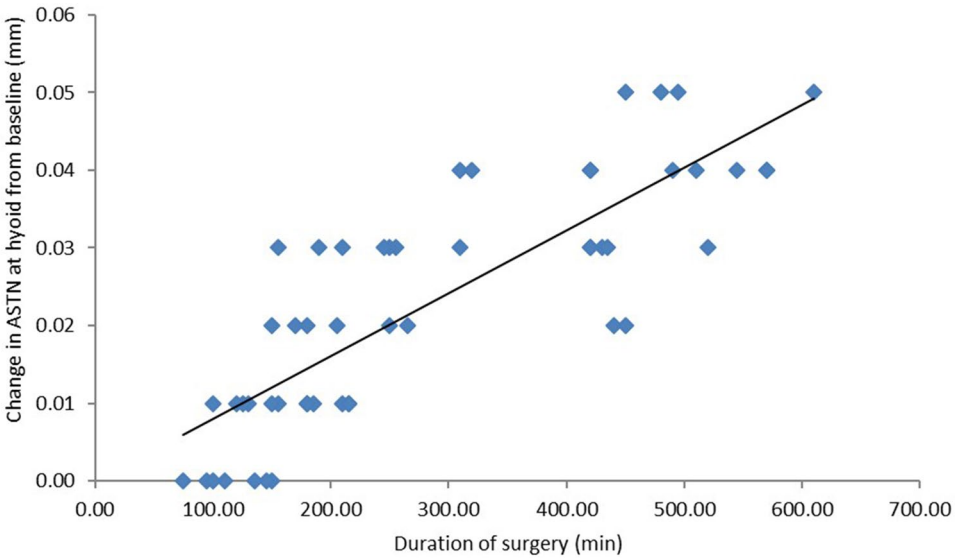

Fig. 1 Scatter plot showing change in the ASTN at the level of hyoid with the duration of surgery

Discussion

The results of our study demonstrated an increase in ASNT at the level of hyoid and the vocal cords on ultrasound evaluation after RALS in steep Trendelenburg position and these changes persisted till 2 h in the postoperative period. Furthermore, increase in tongue thickness, MMG and NC was also seen in the immediate postoperative period.

These changes in the airway dimensions can primarily be attributed to oedema of the neck and peripharyngeal tissues. Administration of general anaesthesia along with positive pressure ventilation increases the central venous pressure and intra capillary pressure [11]. The increase in the capillary hydrostatic pressure leads to interstitial accumulation of fluid in the dependent tissues [11, 12]. In the presence of reduced oncotic pressure, the increased pressures can cause mucosal oedema by altering Starling equation. This increase is further accentuated to almost threefold in steep Trendelenburg position of 45° [13]. The head-down position along with CO_2 insufflation in RALS increases the abdominal pressure, which impedes the venous return from the head and neck. Conglomeration of all these factors can lead to a significant change in the airway dimensions postoperatively in these patients.

We were fortunate that despite significant increase in airway dimensions in the postoperative period, none of our patients developed laryngeal oedema, which could have necessitated tracheal re-intubation. Various factors like airway manipulation and increased endotracheal cuff pressure can cause laryngeal oedema. In our study, tracheal extubation was performed after cuff leak test to rule out laryngeal oedema. The endotracheal cuff pressure was regularly monitored and maintained to less than 30 cm H_2O. The patients were nursed in head up position in the PACU. The use of the head-upright position prior to extubation, diuretic use and extubation itself has been stated to improve the upper airway obstruction symptoms [14].

However, desaturation ($SpO_2 < 94\%$) in the immediate postoperative period was seen in four patients which was rectified after insertion of the nasal airway. Oksar et al. reported upper airway obstruction-like clinical symptoms in 12.5% of the patients undergoing RALC [15].

Significant increase in ASTN at the level of hyoid was seen till 2 h postoperatively. The increase in thickness of the anterior tissue at the level of hyoid postoperatively is an important finding as it signifies the region where the tip of laryngoscope blade resides and needs to be displaced for successful intubation [10, 16].

The results of our study demonstrated a strong correlation between ASNT at the level of hyoid and duration of surgery and amount of intraoperative i.v. fluid administered. In contrast, Ushiroda et al. showed weak correlations between changes in airway dimensions and intra-operative fluid balance as well as surgical duration in prone position [17]. So far, none of the studies have evaluated postoperative airway changes in Trendelenburg position; therefore, no direct comparison can be made with our study.

Postoperative airway compromise following RALP in steep head down position has been postulated to be seen more often in patients with increased duration of surgery lasting more than 3 h or patients receiving over-enthusiastic fluid therapy exceeding 3 l [13]. In our study lactated ringer solution was given at 4–6 ml/kg as maintenance fluid. Restricted intraoperative fluid administration had dual advantages. First it minimises the amount of supraglottic oedema and second it decreases excessive urine output which prevents obscuring of operative field during urethrovesical anastomoses and bladder neck anastomses.

Furthermore, our study showed these changes persist till 2 h postoperatively. Therefore, in cases of prolonged surgery, the extubation can be delayed and patients can be nursed in head up position in the postoperative period.

An increase in MMP in the immediate postoperative period can be attributed to the gravity-related increased hydrostatic pressure causing tissue oedema and increase in tongue thickness. The accuracy of MMG may be affected by differing levels of patient co-operation in post surgery patient [18, 19]. We tried to obviate the proposed errors by careful instructions with regard to maximum mouth opening and tongue protrusion without phonation before each photograph. Standardisation of the image acquisition and scoring by a blinded expert was also incorporated to increase the reliability of Mallampati scoring.

The results of our study should be interpreted in the light of certain limitations. First, quantification of tongue thickness, ASTN at the level of hyoid reflects the supraglottic structures. Further studies are needed to study infraglottic changes and deeper structures. Second, ultrasonic quantification often has interobserver bias. Therefore, to limit this bias the sonographic recordings in our study were done by a single investigator. Third, a relatively small sample size was enrolled for study. Large prospective randomised studies are needed in the future to substantiate our results. Ours being a teaching institute, duration of surgery depends on the experience of surgeon and learning curve. Further studies can be done in a set up with relatively similar duration of surgery for uniform comparison. We followed strict inclusion criteria and patients with body mass index (BMI) > 30 were excluded. A significant relationship with the BMI and increased ASNT can be hypothesised and would warrant future trials to make a statement. Last, any interventions which can decrease postoperative oedema like diuretics, role of steroids were not studied.

In conclusion, robot assisted urological procedures in the steep Trendelenburg position result in significant increase in airway dimensions in the postoperative period. This warrants close monitoring during this period for any airway compromise.

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Compliance with ethical standards

Conflict of interest Author Seran Reddy, Author Divya Jain, Author Kajal Jain, Author Komal Gandhi, Author Ravi Mohan, Author Mandeep Kang declare that they have no conflict of interest.

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