CONSIDERATIONS FOR ROBOTICALLY ASSISTED SURGERY

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History: da Vinci surgical system introduced in 1997; became commercially available in 1999; now dominates market

da Vinci system: has 3 components (console, patient-side cart, and vision system); employs field similar to that for open surgery; current generation system is da Vinci SI (allows second console and has fourth robotic arm; integrates multiple data sources); now being used in single-site surgery; by end of 2011, >1500 da Vinci systems in use throughout United States; >2000 systems in use worldwide

Indications approved by Food and Drug Administration (FDA): multiple procedures related to cardiac, thoracic, abdominal, pelvic, and head and neck surgery; currently, pelvic procedures predominate (>66%)

Learning curve: basic outcome measures such as operating room (OR) time and blood loss plateau at ~70 cases; adequate margins in oncologic surgery plateau at 100 to 150 cases; advanced outcomes — most data derived from experience with prostatectomy; minimization of erectile dysfunction and incontinence occurs at 150 to 200 cases; proficiency (ie, outcomes of robotic and open surgery similar) seen at 250 to 400 cases; surgeons self-report needing ≥250 cases to feel comfortable with system

Economics: assuming 77 cases for learning curve, average cost for surgeon to become proficient $200,000; in 2010 comparison, median direct cost to hospital of robotic-assisted prostatectomy >$6700, vs $4400 for open procedure; as of January, 2012, da Vinci SI Firefly system costs $2,185,000, plus $100,000 to $180,000 for annual maintenance contract; average cost per patient >$3500; therefore, more accurate cost estimate may be $10,000 per case for robotic surgery, vs $4400 for open surgery; overall annual return on investment 3% (takes 36 yr for robot to pay for itself); in comparison of effectiveness of minimally invasive with open radical prostatectomy, minimally invasive procedure associated with shorter length of stay and fewer respiratory, medical, and surgical complications, but more genitourinary complications and higher rates of erectile dysfunction and incontinence

Physiologic impact: Trendelenburg positioning associated with 10% to 30% reduction in cardiac output and elevation of pulmonary capillary wedge pressure; pneumoperitoneum associated with 20% increase in systemic vascular resistance (SVR), with corresponding 25% increase in mean arterial pressure; blood supply to mesenteric, renal, and hepatic systems decreased

Hemodynamic implications: in study of 16 patients, robotic prostatectomy associated with doubling of central venous and pulmonary capillary wedge filling pressures; SVR rose initially with creation of pneumoperitoneum, but normalized when patient placed in Trendelenburg position; blood pressure increased by 25%; ventricular stroke work increased by 65%; elevation in central venous pressure (CVP) similar to that seen in heart failure; elevation in pulmonary arterial pressure similar to that seen in pulmonary hypertension; change in stroke work may be risky for patients with preexisting cardiovascular (CV) disease; hyperdynamic state persisted >1 hr postoperatively

Conclusions: patients with compromised systolic function may develop acute heart failure; patients at risk for coronary artery disease may enter demand ischemia

Cardiac function: echocardiographic studies of patients undergoing robotic surgery suggest good preservation of systolic and diastolic function (diastolic function shows no indication of early ischemia)

Patients with known cardiac disease: heart rate reduced and cardiac output preserved (suggests good tolerance of Trendelenburg position)

Pulmonary effects: creation of pneumoperitoneum increases abdominal and intrathoracic pressures; steep positioning mobilizes abdominal visera toward diaphragm and moves diaphragm cephalad; may reduce lung capacity and functional residual capacity (FRC), increase airway pressure, and result in arterial desaturation; need for minute ventilation also necessary to offset hypercarbia

Interventions: neither volume nor pressure control ventilation appear to affect hemodynamics; pressure control associated with better dynamic compliance and lower airway pressure; positive end-expiratory pressure (PEEP) associated with improved compliance, less atelectasis, and preservation of arterial oxygenation (compared with no PEEP)

Intraabdominal effects of pneumoperitoneum: mobilization of blood from splanchnic vasculature may cause acute rise in cardiac preload; prolonged abdominal pressure may decrease flow through inferior vena cava and eventually resulting lowering preload; decreased mesenteric perfusion may result in ischemia of gut; hepatic and portal perfusion fall, with rise in transaminases; renal cortical and medullary perfusion also decrease, with subsequent decrease in urinary output; neurohormonal effects include rise in vasopressin and 5. Recognize indications for diagnostic testing after robotic surgery.

Educational Objectives

The goal of this program is to improve the management of anesthesia in patients undergoing robotically assisted surgery. After hearing and assimilating this program, the clinician will be better able to:

1. Consider the number of cases required before a surgeon becomes proficient at robotic surgery.
2. Identify the major physiologic effects resulting from the interplay of positioning and pneumoperitoneum in robotic pelvic surgery.
3. Anticipate and manage complications associated with robotic surgery.
4. Perform a preoperative evaluation on patients scheduled to undergo robotic surgery.

Faculty Disclosure

In adherence to ACCME Standards for Commercial Support, Audio-Digest requires all faculty and members of the planning committee to disclose relevant financial relationships within the past 12 months that might create any personal conflicts of interest. Any identified conflicts were resolved to ensure that this educational activity promotes quality in health care and not a proprietary business or commercial interest. For this program, Dr. Mensch and the planning committee reported nothing to disclose.
Anesthetic management:头-下定位增加风险，当颅内压（ICP）和脑水肿升高；CVP升高，对颅内静脉回流产生风险；在研究21名患者接受颅内超声多普勒测量的患者中，出现机器人前列腺切除术时，脉冲性和阻力性保持稳定；在头低位患者的脑表面血液动力学保持稳定，研究使用近红外光谱学未见脑缺血；近红外光谱学研究使用近红外光谱学未见脑缺血；措施有效脑血流动力学保持稳定；研究结果表明，没有增加脑血流动力学；

Cerebral hemodynamics:头-下定位增加风险，当颅内压（ICP）和脑水肿升高；CVP升高，对颅内静脉回流产生风险；在研究21名患者接受颅内超声多普勒测量的患者中，出现机器人前列腺切除术时，脉冲性和阻力性保持稳定；在头低位患者的脑表面血液动力学保持稳定，研究使用近红外光谱学未见脑缺血；近红外光谱学研究使用近红外光谱学未见脑缺血；措施有效脑血流动力学保持稳定；研究结果表明，没有增加脑血流动力学；

Complications:复杂性——回顾性数据对1500名患者在大体积前列腺切除中心显示低血糖的风险，需要血液稀释，导致患者围术期并发症；rare cases of massive or fatal carbon dioxide absorption 3% to 5%; mixed acidois may occur in at-risk patients

Access-related complications: 相似于在腹腔镜手术中，脊髓神经损害，手术系统，需要止血和预防性机械通气

CV complications: 非阵发性，包括一个报告的阵发性，临床意义不明；无导致急性或慢性碳氧化物吸收；率的术后并发症，如心房颤动或心肌梗死或充血性心力衰竭

Neurologic: 脑干缺血（降低到1%，当眼睛被密封的胶布）

Failure of robotic system: 在研究中1900名患者未报于FDA，3%与患者有关

Complications associated with pneumoperitoneum: 碳氧化物气腹术的并发症常见；包括识别和修理不采用腹腔镜手术

"innocent bystander" injuries — occur outside surgical field

Access-related complications: 相似于在腹腔镜手术中，脊髓神经损害，手术系统，需要止血和预防性机械通气

CV complications: arrhythmias, including one report of asystole due to inadvertent compression of patient’s neck by system (reflects lack of tactile feedback inherent in system); myocardial infarction or congestive heart failure among at-risk patients; refractory hypertension due to hypercarbia

Pulmonary: elevated CVP, pulmonary edema, barotrauma, atelectasis, pneumothorax, and capnolorthax

Neuromuscular: injuries associated with extreme positions required by robotic surgery (eg, compartment syndrome due to prolonged maintenance of lithotomy position)

Neurologic: case reports of cerebral hemorrhage, paradoxical air embolism, failure of surgical system, and need for postoperative mechanical ventilation; rate of corneal abrasions 3% (lowered to ≤1% when eyes sealed with film dressing [eg, DermAssist, SureSite, Tegaderm])

Failure of robotic system: in study of n=1900 failures reported to FDA, <3% associated with harm to patients

Access-related complications: similar to those in laparoscopic surgery; include major vascular or bowel injury (difficulties include identifying injury and repairing without converting procedure); “innocent bystander” injuries — occur outside surgical field

CV complications: arrhythmias, including one report of asystole due to inadvertent compression of patient’s neck by system (reflects lack of tactile feedback inherent in system); myocardial infarction or congestive heart failure among at-risk patients; refractory hypertension due to hypercarbia

Pulmonary: elevated CVP, pulmonary edema, barotrauma, atelectasis, pneumothorax, and capnolorthax

Neuromuscular: injuries associated with extreme positions required by robotic surgery (eg, compartment syndrome due to prolonged maintenance of lithotomy position)

Neurologic: case reports of cerebral hemorrhage, paradoxical air embolism (leading to hemiparesis); 7 cases of posterior ischemic optic neuropathy on record

Anesthetic management: preoperative assessment — identify specific factors that may increase patient’s risk associated with prolonged pneumoperitoneum or extremes of positioning; note patient-related factors that may contribute to difficulty of procedure

Nervous system evaluation: contraindications to robotic pelvic surgery — history of cerebrovascular accidents, presence of cerebral aneurysms, and conditions related to elevated ICP or glaucoma; identify preexisting neuropathy

CV evaluation: look for cardiomyopathy and coronary artery disease; explore murmurs with echocardiography; moderate to severe regurgitant lesions contraindicate extreme positioning; perform electrocardiography; x-ray of chest indicated when heart failure suspected

Pulmonary evaluation: look for reactive airway disease (may not be of concern) chronic obstructive pulmonary disease, bullous emphysema, and spontaneous pneumothorax “are probably contraindications”

Renal evaluation: use protective strategies in cases of renal insufficiency; renal failure contraindicates robotic surgery

Miscellaneous: age may be risk factor for postoperative mechanical ventilation and admission to intensive care unit; obesity associated with risk for prolonged operation, higher ventilatory pressures, and lower intraoperative arterial saturation; absolute contraindications — diaphragmatic hernia, coagulopathy, and sickle cell disease

Patient-related factors: morbidity obesity and conditions associated with adhesions increase risk for complications; preoperative preparation — terminate antiplatelet therapy 2 wk preoperatively; begin clear fluid diet 1 day before surgery; nothing by mouth after midnight; laxatives or suppositories before pelvic surgery; psychologic preparation recommended (identify complications and side effects; reassure and prepare patient for early discharge); preoperative holding — type blood and place 2 peripheral intravenous (IV) lines; administer multimodal analgesia and antibiotics; antithrombotic prophylaxis with heparin considered standard of care; gastric prophylaxis also widely employed; standard monitors usually used; for patients at risk for early discharge; for patients needing central IV lines for vasocactive drugs may not be good candidates for robotic surgery; place pulmonary artery catheters for pulmonary hypertension, and cardiac output monitoring for cardiomyopathy; transesophageal echocardiography recommended in cases of unexpected hemodynamic compromise

Induction and intubation: follow general clinical practice; use general anesthesia; obtain secure airway; mechanical ventilation indicated to manage hypercarbia; continuous muscle paralysis necessary; nitrous oxide widely used but disliked by many surgeons; visceral distention may obstruct view; low-opioid technique preferred; neuromuscular techniques usually avoided due to early patient discharge, but thoracic epidural catheter recommended for cystectomy with ileal conduit

Positioning for pelvic robotic surgery: friction between patient and table should be increased; both arms should be tucked, with hands maintained in neutral position; consider extra protection for ulnar, radial, and medial nerves; move patient into lithotomy position; before prepping and draping patient, speaker and colleagues move patient into steep Trendelenburg position (30°–45°) to confirm that patient will not move and hemodynamics remain stable; padded boot stirrups (eg, Yellofins) provide protection against injuries to knees during positioning of robot

Intraoperative management: ventilation complicated by decreased compliance and change in lung volume (pressure-control ventilation and PEEP recommended); mild hyperventilation used; perfusion-related issues — prophylactic arterial vasodilation recommended for patients at risk for cardiac failure or myopathy; α2 agonists recommended for patients at risk for demand ischemia; for patients at risk for elevated ICP, protective strategies such as fluid restriction, mannitol, or normocapnia recommended; consider nicardipine or mannitol for patients at risk for renal insufficiency; if patient at risk for compartment syndrome, frequently check tissue turgor of calves and consider repositioning legs every 2 hr; neuro muscular blockade absolutely required while robot is down (continuous administration via port infusion, with train-of-4 monitoring recommended); excessive fluid administration associated with facial edema and swelling of airway and conjunctiva; excessive urine production during prostatectomy may obstruct surgeon’s high-magnification field (fluid restriction requested until completion of urethral Anastomosis); use of intermittent compression devices lower risk for deep venous thrombosis associated with prolonged lithotomy position (preoperative heparin standard of practice); gastric decompression, H2 proton pump inhibitors, and securing eyes tightly with film dressing recommended for preventing oral, facial, and ocular burns associated with regurgitation of stomach contents
Emergence: terminate neuromuscular blockade as soon as robot undocked; with patient out of Trendelenburg position, apply recruitment maneuvers and sigh breaths to overcome atelectasis; elevate patient’s head to promote drainage; maintain mechanical ventilation until extubation; additional narcotics unnecessary; delayed return of cognitive function associated with prolonged pneumoperitoneum possibly underreported.

Postoperative care: standard monitoring for general anesthetic; maintain elevation of head; check hemoglobin levels; check arterial blood gases if hypercarbia or postoperative hypoxia suspected; chest x-ray indicated if pneumothorax or significant subcutaneous emphysema suspected; prescribe nonsteroidal anti-inflammatory drugs for remainder of stay (consider presence of occult injury if patient complains of significant postoperative pain); treat bladder spasms with opioids and belladonna suppositories; evaluate mental status before discharge; perform cursory evaluation for postoperative neuropathy; treat oliguria with fluid boluses; notify primary care service for follow-up.

Robotically assisted general surgery: procedures usually performed in head-up position; well tolerated; overhead docking of robot obscures airway access and visibility; high pneumoperitoneal pressures may increase risk for pneumothorax and tension pneumothorax; head and neck (transoral robotic) surgery — used for resection of low-grade tumors at tongue base or deep pharynx; surgeon controls airway; often asks for wire-reinforced tubes; procedure includes planned postoperative intubation for 24 to 48 hr (extubation before leaving OR unnecessary).

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1. Surgical proficiency at robotically assisted prostatectomy, defined as similarity of outcomes to those with open surgery, is believed to occur after _______ cases.
   (A) 70 to 150  (B) 125 to 300  (C) 250 to 400  (D) 350 to 500

2. Compared to open radical prostatectomy, minimally invasive prostatectomy is associated with:
   1. Higher rates of erectile dysfunction
   2. Shorter length of stay
   3. Fewer respiratory complications
   4. Lower rates of incontinence
   (A) 1,2,3,4  (B) 1,2,3  (C) 1,3  (D) 2,4

3. The Trendelenburg position is associated with an increase in all the following, except:
   (A) Blood pressure  (B) Central venous pressure  (C) Ventricular stroke work  (D) Cardiac output

4. Possible intraabdominal effects of pneumoperitoneum include:
   1. Ischemia of the gut
   2. Polyuria
   3. Reduced hepatic perfusion
   4. Inhibition of renin-angiotensin system
   (A) 1,2,3,4  (B) 1,2,3  (C) 1,3  (D) 2,4

5. Rates of complications associated with pneumoperitoneum during robotically assisted surgery are _______ those reported for laparoscopic surgery.
   (A) Similar to  (B) Higher than  (C) Lower than

6. The risk for major bowel or vascular injuries appears to be higher with robotic than with standard laparoscopic prostatectomy.
   (A) True  (B) False

7. Which of the following contraindicate robotic pelvic surgery?
   (A) History of cerebrovascular accident  (C) Renal failure
   (B) Diaphragmatic hernia  (D) All the above

8. It is recommended that antiplatelet therapy be discontinued _______ before robotic surgery.
   (A) 48 hr  (B) 72 hr  (C) 1 wk  (D) 2 wk

9. Which of the following statements about induction and intubation for robotic surgery is accurate?
   (A) Secure airway rarely needed
   (B) Avoid mechanical ventilation whenever possible
   (C) Continuous muscle paralysis necessary
   (D) Neuraxial techniques used in large proportion of cases

10. Extubation of a patient undergoing robotically assisted head and neck surgery is performed:
    (A) As soon as the robot is undocked
    (B) Just before the patient leaves the operating room
    (C) While in postanesthesia care
    (D) 24 to 48 hr after surgery

Answers to Audio-Digest Anesthesiology Volume 54, Issue 17: 1-A, 2-D, 3-D, 4-A, 5-B, 6-C, 7-C, 8-D, 9-B, 10-D