Thoracic Surgery and Fluid Management: How Little Is Enough?

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OBJECTIVES

1. Review the current theories concerning the causes of acute lung injury after lung resection surgery for cancer.
2. Review the current recommendations for perioperative fluid management of patients having lung resection surgery.
3. Review the current recommendations for intraoperative ventilatory management in lung resection surgery.
4. Review the preoperative preparation of complex and high risk patients and discuss what interventions make a significant difference.

STEM CASE - KEY QUESTIONS

The patient was a 65 year old man with an 80 pack/year history of cigarette smoking who presented one month prior to surgery with the chief complaint of a productive cough of increasing frequency and severity and a 20 pound (involuntary) weight loss.

The patient was seen by his primary care provider who noted the patient coughed frequently during the visit and produced blood-tinged sputum. Sputum samples were sent for culture and cytology. She noted the patient's weight was 25 pounds lower than when the patient had last been seen six months before. The patient was short of breath with minimal exertion (talking, walking from the chair to the exam table). The PCP found "large airway sounds" (rhonchi with end expiratory wheezes) over the upper half of the right lung fields. Cardiac exam showed a resting tachycardia with occasional premature beats. The patient's fingers were yellow-stained and clubbed. There was a suggestion of a cyanotic tinge to the nail beds and lips. Laboratory workup and chest xray were ordered. The ECG showed a heart rate of 111, peaked "P" waves in lead II and poor "R" wave progression across the "V" leads. The PCP referred the patient to a pulmonary specialist.

The pulmonalogist reviewed the chest xray ("multiple nodulary densities noted throughout the right lung field and in the left upper lobe, some of which are calcified. There is peri-hilar fullness and the pulmonary vasculature is prominent") and sputum cytology ("atypical cells noted") and recommended a bronchoscopy and chest CT scan. Six of eight biopsies from the right lung showed "non-small cell carcinoma". The left lung biopsies revealed inflammatory tissue but not malignancy. The patient was then referred to a thoracic surgeon.

The patient was seen by the thoracic surgeon one week before surgery. The thoracic surgeon's history and physical examination were consistent with that of the PCP and pulmonalogist. After reviewing the chest xray, thoracic CT scan, and bronchoscopy results, she discussed surgical intervention. The patient agreed to an exploratory thoracotomy with the options ranging from biopsy and wedge resection to right pneumonectomy.

The patient was referred to your preoperative clinic the day before surgery. During your interview, you find a history of hypertension, well-controlled on a thiazide diuretic and an ACE

inhibitor, elevated lipids treated with a 'statin', and COPD. The patient uses several inhalers and his breathing is comfortable at rest. The patient admits to social use of alcohol and notes he stopped smoking cigarettes 10 days ago. Your physical exam is consistent with those noted above. In addition to what has already been noted, your review of the available workup shows a serum albumin of 3.0 mg/dl (nl 3.8-5), a cholesterol of 90 mg/dl (acceptable range 0-199), and a hematocrit of 55% (nl 38-51) with an MCV of 110 (nl 85-98) and serum GGT of 780 (nl 25-75). Other laboratory workup was unremarkable. PFT's obtained a week ago show FEV_1 of 1.32L (32% of predicted), FVC of 4.02 (90% of predicted), DLCO of 8% and MVV of 45. Cardiology consult and results of TEE done yesterday are pending.

You discuss anesthetic options with the patient who agrees to general anesthesia with arterial line placement. He also agrees to thoracic epidural catheter placement and postoperative spinal infusion as well as intraoperative TEE and central line placement if necessary. The possibility of prolonged postoperative mechanical ventilation was also discussed.

The patient has his last PO intake at 10:00 p.m. on the evening before surgery. He is admitted to your medical center at 0600 on the morning of surgery and has an IV placed at 0630 hours. The IV rate is set at 75 cc/h (1cc/Kg). The patient is brought to the OR where a thoracic epidural and radial artery catheter are placed followed by induction of general anesthesia. The thoracic surgeon arrives and tells you she does not want this patient to have more than a liter of (IV) fluid for the case as she is worried about his postoperative course. You promise to do your 'best' for the patient.

The patient has a bronchoscopy followed by a right pneumonectomy. During one lung ventilation you use tidal volumes of 5-6cc/k and limit maximum airway pressure to 45-50 cm of water. The surgery takes five hours to complete. The patient received 1.5 liters of Ringer's Lactate and 500cc of Hespan. EBL was 250cc and urine output 250cc.

The patient is transported from the OR to the SICU with the endotracheal tube in place and mechanical ventilation is continued. An epidural infusion consisting of 0.1% bupivacaine and fentanyl 5 mcg/ml, running at 8cc/hour, was started on arrival in the SICU. Vital signs include a heart rate of 108, blood pressure of 112/67, temperature 35.5°C, and a pain score of 3/10. SpO_2 is 94% on 3L NPO_2. The patient is sleepy but is easily arousable and follows commands. He shakes his head "No" when asked if he has pain. Mechanical ventilation is weaned and the endotracheal tube is removed. The patient received supplemental oxygen (40%) by ventimask. Chest xray shows hyperinflation of the left lung with a "suggestion of increase vascular markings". Kerley (B) lines are noted. Total IV fluid rate is set at 75 cc/hour. Four hours after admission to the SICU the patient's blood pressure is noted to be 82/48. Surgery is called and orders a dopamine infusion titrated to a systolic blood pressure of 100. Initial laboratory workup drawn on arrival is reviewed and shows normal electrolytes, BUN and creatinine. Hematocrit was 44%. Arterial blood gas showed a pH of 7.38, PCO_2 of 50, pO_2 of 100, and base excess of +5.2 on a "100% non re-breather" mask. The dopamine infusion is gradually increased to 12 mcg/K/min in order to maintain BP. The patient is re-intubated, mechanical ventilation is re-initiated and he is sedated. Urine output is noted to be 180cc for the first eight hours the patient is in ICU. Laboratory workup from midnight is significant for a serum creatinine of 2.1 mg/dl (nl 0.8-1.3) and BUN of 80 mg/dl (nl 7-21). Systolic BP (SBP) is in the 95-100 mmHg range. Dopamine is decreased to 5 mcg/K/min. SBP remains in the 90's and urine output falls to 50cc

for the second 8 hours that the patient is in the ICU. A Swan Ganz catheter is placed and shows central venous pressure, pulmonary artery pressures and pulmonary artery occlusion pressures in the normal range. The patient is given a fluid bolus of 250cc of normal saline and one unit of fresh frozen plasma with no change in vital signs, hemodynamic parameters or urine output. The patient then receives two doses of intravenous furosemide of 20 and 40 mg one hour apart with no noticeable effect. Stat laboratory workup from 6:00 a.m. is significant for a creatinine of 3.0 mg/dl and a BUN of 100. Hematocrit is 38%. An urgent Renal Medicine consult is obtained. The consultant recommends IV hydration and no further furosemide. She recommends stopping dopamine and suggests watchful waiting with dialysis/ultra-filtration as a possibility. The patient receives one liter of normal saline over four hours on orders of the attending staff surgeon. The epidural infusion is also stopped. Noon laboratory values show a creatinine of 4.2 mg/dl, hematocrit of 28% and serum albumin of 2.0.

The renal consultant returns and suggests increasing hydration using colloids, principally two units of pRBC's. The patient receives the transfusion along with 25 grams of albumin. The patient's SBP stabilizes in the 100 range. There is no change in central venous pressure, pulmonary artery pressures or pulmonary artery occlusion pressure. Urine output is 50cc for eight hours and hemodynamic parameters remain unchanged.

Laboratory workup from 8:00 p.m. on POD #1 is significant for a creatinine of 3.5 mg/dl and a hematocrit of 30%. Urine output increase to 150-180cc per eight hours.

Gradually, over the next four days, the serum creatinine decreases and stabilizes at 2.0mg/dl. Further transfusion of 2 units of pRBC's is necessary to maintain hematocrit in the 28-30% range. Oral intake with supplemental enteral feedings are aggressively encouraged. The patient is weaned from mechanical ventilation and is extubated on POD#5.

Questions:

1. What additional information would you have asked for before administering the anesthetic in the case? (That is what information that you didn't know might have changed your anesthetic plan?)

2. Was this patient at high risk for acute lung injury in the postoperative period? Why?

3. Was the intraoperative fluid management of this patient appropriate?

4. Was the intraoperative ventilatory management of this patient appropriate? How would you have altered what was done?

5. Would you have placed an epidural? Would you have used the epidural for postoperative pain control? What would you have choosen for an infusion if an epidural was used for postoperative pain control?

6. Are the abnormal findings on the initial CXR obtained in the ICU of any significance (especially in the face of a patient without signs or symptoms of pulmonary edema)?

7. Do you agree with the fluid management in the postoperative period? Would you have changed it in any way?

8. Do you agree with stopping the epidural infusion? Why? Does pain control matter in this situation? Why?

9. Do the normal hemodynamic parameters obtained from the SG catheter preclude or include any specific cause for the patients medical problems?

10. How long must the patient obstain from cigarette's before surgery to derive beneficial effects? What about second hand smoke?

11. Knowing what you (now) know about acute lung injury do you agree or disagree with the surgeon's management in the postoperative period?

PROBLEM BASED LEARNING DISCUSSION

Acute lung injury (ALI) is the cause of significant morbidity and mortality after thoracic surgery[1]. While ALI may be caused by a variety of underlying medical (ARDS, congestive heart failure) and surgical (air leak, bronchopleural fistula) problems some cases cannot be traced to specific etiologies. These cases have been associated with pneumonectomy ("postpneumonectomy pulmonary edema"), "larger amounts of intra-operative fluid administration and "high" postoperative urinary output. Other risk factors noted have been the type of resection, (pneumonectomy more frequently than lobe resection), the side of surgery (right more often than left), administration of fresh frozen plasma, high intraoperative airway pressure during one lung ventilation, mediastinal lymphatic drainage, postoperative mediastinal position[1], serum cytokines, oxygen toxicity, preoperative alcohol abuse and poor postoperative pain control. The tumor histological pathology, disease stage, preoperative medical status, smoking history and preoperative medication use do not appear to be associated with this idiopathic form of ALI[3].

A recent retrospective study found a bimodal distribution for the appearance of ALI (total incidence 4.2%) after lung resection, with cases presenting early (POD# 0-3) and late/delayed (POD#3-12)[2]. The late onset/delayed cases were associated with specific causes while the early onset seemed not to have adverse events associated with them. They noted a 26% mortality after early and a 60% mortality after late onset ALI[2]. The authors identified 4 independent risk factors for the development of early ALI in their population. These were 1.high intraoperative ventilatory pressures, 2."excessive" fluid infusion, 3.pneumonectomy, and 4. preoperative alcohol abuse. While the extent of the resection performed is not under the control of the anesthesiologist, the other 3 risk factors are to a certain extent controllable at least on a limited basis. Cessation of cigarette smoking and alcohol "abuse", defined in this study as more than 60g of ethanol consumption per day, would be desirable endpoints of patient education in the pre-operative period. However, "how long is long enough" for smoking or alcohol cessation? There is no evidence that short-term smoking cessation, days to weeks as seen in this patient, improves postoperative outcomes in any type of surgery[4]. Nor can we estimate for how long alcohol abstinence would need to take place before a beneficial effect, if any would be seen. Combine this with the urgency to remove a know malignancy and we should view the anesthesiologist role

as an additional educator in the preoperative period helping patient make informed (and better) postoperative lifestyle choices.

The matter of excessive fluid administration and intraoperative ventilator management, while more contentious then other risk factors associated with this form of ALI are more within the control of the anesthesiologist. Several studies have shown that early onset ALI can be reduced (but not eliminated) by careful perioperative fluid management. Fluid administration of less than 3-4 liters in the first 24 hours or lower positive "fluid balance", 10ml/k over the first 3 day have been associated with reduced incidence of ALI[5]. This is likely due to the increased capillary permeability of the nonoperative lung after pneumonectomy[1]. A strategy to limit fluid administration while still allowing sufficient intravascular volume to prevent hypotension and renal complications may be the use of colloids such as blood products and starches. It is of note that fresh frozen plasma has been associated with an increased incidence of ALI. Also, fluid management guided by pulmonary artery catheter insertion is unlikely to helpful, as this form of ALI is associated with "normal" hemodynamics In addition to limiting fluid and reducing the incidence of ALI the risk of renal complications such as occurred in this patient must be taken into account. The fluid management decisions made in this high risk patient were done with the intent of limiting his chances of developing an early onset ALI, but in retrospect one set of complications were simply traded for another.

Less emotional content is contained in the findings that lower ventilation pressures and volumes may help protect the pneumonectomy patient form ALI. The standard use of large tidal volumes (10-12ml/kg) during one lung ventilation may combine with "auto-PEEP" and increased functional residual capacity that develops in these patients to bring the non-operative lung to the volumes associated with ventilator-induced lung injury. A recent editorial[1] recommended use of lower tidal volumes (5ml/kg) and limiting plateau inspiratory pressures to less than 25 cm H2O. These recommendations were incorporated into the management of the patient at hand who despite his difficulties did not develop ALI.

REFERENCES

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LEARNING SUMMARY

1. Review the causes of acute lung injury after pulmonary resection.
2. Review the current recommendation for fluid management in lung resection surgery.
3. Review the current recommendations for intraoperative ventilatory management in thoracic resection surgery during one lung ventilation.