

- patients with dissociated sensory loss. *J Neurol Neurosurg Psychiatr* 26:211-219, 1963
19. Larson SJ, Holst RA, Hemmy DE, et al: Lateral extracavitary approach to traumatic lesions of the thoracic and lumbar spine. *J Neurosurg* 45:628-637, 1976
20. Jasper HH: The ten twenty electrode system of the International Federation. *Electroenceph Clin Neurophysiol* 10: 371-375, 1958
21. Grundy BL, Brown RH, Clifton PC: Effect of droperidol on cortical evoked potentials (abs). *Electroencephal Clin Neurophysiol* 50:158P-159P, 1980
22. Donchin E, Callaway E, Cooper R, et al: Publication criteria for studies of evoked potentials (EP) in man, Attention, Voluntary Contraction and Event-Related Cerebral Potentials. *Prog Clin Neurophysiol*, 1. Edited by Desmedt JE. Basel, Karger, 1977, pp 1-11.

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Massive Intraoperative Pulmonary Tumor Embolus from Renal Cell Carcinoma

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Renal cell carcinoma occasionally invades the inferior vena cava (IVC). In such patients a radical nephrectomy and complete removal of the tumor thrombus from the IVC is required.¹ Intraoperative problems encountered include massive hemorrhage, decrease in venous return due to manipulation of the IVC, tumor obstruction of the outflow of the right ventricle,² and air and tumor pulmonary embolus.³ Fatal results have been reported with massive tumor embolization to the lungs during surgery.⁴ This report describes the recognition and successful treatment of intraoperative massive tumor embolus to the lungs by the rapid institution of cardiopulmonary bypass (CPB) and removal of the tumor from the pulmonary artery.

REPORT OF A CASE

A 15-year-old girl, weighing 57 kg, was admitted for investigation of shortness of breath, chills, fever, dry cough, and chest wall and back pain. Physical examination revealed a pale girl with decreased breath sounds in the right lower lung field and a palpable mass in the right upper quadrant of the abdomen. The hemoglobin was 10.9 g/dl. Electrolytes, platelet count, prothrombin time, partial thromboplastin time, blood urea nitrogen, creatinine, and serum glutamic oxaloacetic transaminase were within normal limits. Lactic acid dehydrogenase was elevated to 266 IU/l

(normal 0-110). The chest roentgenogram revealed a large right-sided pleural effusion, which was drained preoperatively, with bilateral basal inflammatory changes. A renal arteriogram revealed a large mass arising from the mid portion of the right kidney. Venous angiography showed the IVC to be totally occluded at the level of T 12 (fig. 1).

After the intravenous administration of diazepam, 7.5 mg, and fentanyl, 25 μ g, a left radial artery catheter and a right atrial catheter were inserted under local anesthesia for continuous monitoring of arterial blood pressure and central venous pressure (CVP). Anesthesia was induced with thiopental, 300 mg, intravenous (iv), and after succinylcholine, 60 mg, iv, the trachea was intubated. Anesthesia was maintained with 50 per cent nitrous oxide, halothane at an inspired concentration of 0.5-1.0 per cent, 25 μ g increments of fentanyl, and pancuronium.

With CPB available on standby and the patient in the right lateral decubitus position, a radical nephrectomy was performed. The pH_a was 7.38, Pa_{O_2} 220 torr, Pa_{CO_2} 39 torr, HCO_3^- 22 mEq/l, 30 min after induction of anesthesia. Following control of the IVC at the diaphragm and bifurcation, the tumor thrombus was removed from the IVC. After closure of the venotomy, when all thrombus was thought to have been removed and the cava irrigated with normal saline, a sudden decrease in arterial blood pressure from 110 torr to 30 torr systolic occurred. A sinus tachycardia of 125 beats/min and cyanosis immediately followed. With an increase in the CVP from 4 to 32 cm H_2O , absence of a mill-wheel murmur, and inability to aspirate air through the CVP catheter (to rule out air embolism), the diagnosis of pulmonary tumor embolus was made. Ventilation with 100 per cent O_2 and a dopamine infusion were immediately instituted. The patient was then turned to the supine position in preparation for a median sternotomy. After heparinization (200 units/kg) and cannulation of the right femoral artery, CPB was instituted following sternotomy and cannulation of both vena cavae. The time from the beginning of hypotension to commencement of CPB was approximately 10 min, during which time cardiac arrest occurred requiring closed and then open cardiac massage. Sodium bicarbonate (50 mEq) and dexamethasone (20 mg) were given intravenously. After the cavae had been snared, the main pulmonary artery was opened and large amounts of tumor thrombus was removed with forceps from both the left and right pulmonary arteries. Residual tumor was removed by using a Fogarty catheter and by having both pleural spaces opened and both lungs manually compressed. After closure of the pulmonary artery, the patient could not be

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FIG. 1. Injection of radiopaque material into the vena cava, demonstrating complete occlusion at the level of T 12.

weaned from CPB due to hypotension and distention of the right ventricle. At this time both the right atrium and the pulmonary artery were opened. Inspection of the atrium and right ventricle revealed no presence of tumor. However, the pulmonary artery contained a large amount of residual tumor thrombus, which was removed. After insertion of a pulmonary artery and left atrial pressure catheters, CPB was discontinued uneventfully. The pupils were dilated prior to CPB but decreased in size with the institution of CPB. Protamine sulphate was given after the heart had been decannulated, and anesthesia was maintained with nitrous oxide, oxygen, and intermittent administration of fentanyl. During CPB, pH_a was 7.40, Pa_{O_2} 260 torr, Pa_{CO_2} 27 torr, HCO_3 18 mEq/l. Whole blood (5.0 l), fresh frozen plasma (0.6 l) and crystalloid solutions (6.0 l) were infused during surgery. The patient was transferred to the intensive care unit where she re-

covered with no neurological sequelae. She was discharged from the hospital on the eighth day after surgery and returned for chemotherapy. Pathology revealed adenocarcinoma of the right kidney, with sections from the pulmonary artery samples showing organized clots and tumor mass similar to the renal primary.

DISCUSSION

This case illustrates the intraoperative diagnosis and successful treatment of massive pulmonary tumor embolus arising from renal cell carcinoma invading the IVC. The possibility of IVC obstruction should be considered in patients with lower extremity edema, varicocele, dilated superficial abdominal veins, albuminuria, pulmonary embolus, a right atrial mass, or nonfunctioning of the involved kidney.⁵ Extracorporeal circulation has been used for renal tumor removal from the right atrium⁶ and the use of an umbrella filter in conjunction with CPB⁷ has been recommended to prevent pulmonary embolization from caval tumor thrombus. No other case of intraoperative massive pulmonary renal cell tumor embolus and successful treatment has been reported.

The diagnosis of intraoperative pulmonary tumor embolism was made due to the rapid decrease in blood pressure and marked elevation in the CVP. The possibility of air embolism was also considered but failure to detect a millwheel murmur from the esophageal stethoscope, or aspirate air from the CVP catheter ruled against this. Perhaps prior insertion of a Swan-Ganz catheter might aid in the diagnosis of this condition.⁸ More sensitive methods of detecting air embolization, such as a pre-cordial doppler,⁹ or end-tidal CO_2 determination,¹⁰ may be of benefit. Cardiovascular compromise may also be detected if the patient's blood pressure is higher in the right lateral position if there is tumor involvement and obstruction of the tricuspid valve.² Although a potential problem, clamping of the IVC resulted in no hemodynamic changes, suggesting that the patient had developed sufficient collateral circulation.

In conclusion, a case of massive intraoperative pulmonary tumor embolus from renal cell carcinoma invading the IVC is presented. The condition was immediately recognized and treated by CPB support, which had been available on stand-by, and by removal of tumor embolus to the pulmonary artery. This led to a successful outcome.

REFERENCES

1. Clayman RV, Gonzales R, Fraley EE: Renal cell cancer invading the inferior vena cava: Clinical review and anatomical approach. *J Urol* 123:157-163, 1980
2. Utley JR, Mobin-Uddin K, Segnitz RH, et al: Acute obstruction of tricuspid valve by Wilm's tumor. *J Thorac Cardiovasc Surg* 66:626-628, 1973

3. Judd ES, Scholl AJ: Thrombosis and embolism resulting from renal tumors. *JAMA* 82:75-78, 1924
4. Marshall VF, Middleton RG, Holswade GR, et al: Surgery for renal cell carcinoma in the vena cava. *J Urol* 103:414-420, 1970
5. Schefft P, Novick AL, Straffon RA, et al: Surgery for renal cell carcinoma extending into the inferior vena cava. *J Urol* 120:28-31, 1978
6. Paul JG, Rhodes MB, Skow JR: Renal cell carcinoma presenting as right atrial tumor with successful removal using cardiopulmonary bypass. *Ann Surg* 181:471-473, 1975
7. Farrell RM, Bloch J, Marshall VF: Caval umbrella to trap emboli in patients with renal cell carcinoma. *Surg. Gynecol Obstet* 139:835-839, 1974
8. Munson ES, Paul WC, Perry JC, et al: Early detection of venous air embolism using a Swan-Ganz catheter. *ANESTHESIOLOGY* 42:223-226, 1975
9. Michenfelder JD, Miller RH, Gronert GA: Evaluation of an Ultrasonic device (Doppler) for the diagnosis of venous air embolism. *ANESTHESIOLOGY* 36:164-167, 1972.
10. Brechner VL, Bethune RWM: Recent advances in monitoring pulmonary air embolism. *Anest Analgesia* 50:255-261, 1971

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Development of Tolerance to Ketamine in an Infant Undergoing Repeated Anesthesia

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Ketamine is useful for sedation of children undergoing repeated radiation treatments. The development of tolerance after multiple administrations of ketamine has been observed in animals, in children 6 months to 16 years of age, and in adults. The present report describes the development of tolerance during multiple administrations of ketamine to an 11-week-old infant undergoing radiation treatment of an orbital tumor.

REPORT OF A CASE

An 11-week-old, 6.4-kg male infant began a series of radiation treatments for retinoblastomas of the right eye. At that time the child was receiving no medications. Outpatient treatment was three times/week for 4 weeks. No premedication was administered. Ketamine was selected as the anesthetic.

An insulin syringe was used to measure the 10 per cent ketamine, which was injected into the quadriceps muscle of the thigh. Injection sites were alternated from thigh to thigh. For the first three treatments a dose of 30 mg of ketamine (4.72 mg/kg) was adequate. However, a total dose of 145 mg, in divided doses, was given over 2 hours on the first day because of a delay in carrying out the simulated treatment before the actual treatment (fig. 1). At the fourth and fifth treatments, ketamine, 35 mg, was inadequate to

prevent movements that interfered with proper positioning. Supplementary injections of 15 and 35 mg, respectively, were necessary. At the sixth treatment a single dose of 50 mg was satisfactory. By the seventh and eighth treatments, this dose was inadequate, so the single dose for the ninth and tenth treatments was increased to 75 mg. The dose selected for the 11th treatment was 85 mg, because some significant movement had occurred during the tenth treatment session. The 12th and 13th (final) treatments were carried out with a dose of 105 mg.

Preliminary positioning for treatment was done during the 5 to 7 min required for the anesthetic to become effective. When the infant became quiet, with only slight movements of the extremities that did not jeopardize proper positioning of the head, final positioning was done. Persistence of vigorous movements of extremities for longer than 10 min after injection was accepted as an indication for a supplemental injection of ketamine.

Respirations and oscillations of the peripheral pulse monitor were observed via closed-circuit television during the brief radiation exposure. At no time was interruption of treatment necessary because of movement of the head during the treatment session. There was no problem with increased salivation. After treatment the child was quietly observed in the recovery room until ready for dismissal.

DISCUSSION

The development of tolerance to ketamine has been described in animals. In rats a decrease in sleep time was noted during a schedule of daily doses over 10 consecutive days.¹ In another study² a 26 per cent decrease in sleep time was noted in rats between the first and second daily doses of ketamine. Similarly, the duration of anesthesia has been noted to decrease in monkeys undergoing successive ketamine anesthesia.³ However, in none of these studies was there a determination of the increase in dose required to produce the same results.

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