IPU
Volume 1

International Perspectives In Urology

Traumatic Injuries of the Genitourinary System

W. Scott McDougal, M.D.
Lester Persky, M.D.

International Perspectives In Urology
Volume 1

Traumatic Injuries of the Genitourinary System

W. Scott McDougal, M.D.

Associate Professor of Surgery (Urology)
Dartmouth Medical School
Hanover, New Hampshire

Lester Persky, M.D.

Professor of Urology
Case Western Reserve Medical School
Cleveland, Ohio

Medical Illustrations by
Barbara N. Rankin, A.M.I.

SANS TACHE
WILLIAMS & WILKINS
Baltimore/London

Made in the United States of America

Library of Congress Cataloging in Publication Data

McDougal, William Scott, 1942–
Traumatic injuries of the genitourinary system.

Includes index.
1. Genito-urinary organs—Wounds and injuries. 2. Traumatology. I. Persky, Lester, joint author. II. Title. [DNLM: 1. Urogenital system—Injuries. WJ100 M137t]
RD571.M33 617′.46 80-14976
ISBN 0-683-05768-5

Composed and printed at the
Waverly Press, Inc.
Mt. Royal and Guilford Aves.
Baltimore, MD 21202, U.S.A.

Traumatic Injuries of the Genitourinary System

Series Editor's Foreword

The pageant of civilization and the improvement of mankind rests with the intermingling of people through migration and the exchange of ideas. Historically, as a lessor culture establishes contact with a higher culture, it learns from its new neighbors; they furnish it with models, both artistic and practical; they serve as its teachers and by imitation it grows. Mankind is not content with imitation but has moved to emulate its teachers and creates new forms for itself.

International Perspectives in Urology is designed to promote an international exchange of ideas. International authorities in urology will contribute to this series in the hopes that world-wide exchange of ideas will enhance the intellectual growth and development of urology. It is further hoped that the free exchange of urologic ideas will improve the quality of urologic care around the globe.

International Perspectives in urology breaks new ground with the publication of this monograph series. I hope that the series will satisfy the needs of urologists around the world and that the benefits of the international exchange of urologic ideas is realized.

JOHN A. LIBERTINO, M.D.
Series Editor

Preface

Traumatic injuries are rarely isolated to one organ system and therefore, when the genitourinary tract is involved, associated injuries are to be anticipated. The nature of the associated trauma often modifies the type of therapy employed for the urologic injury. Moreover, trauma may cause alterations in the function of the heart, lung, kidney and body metabolism even though these systems have not been directly injured. For these reasons, the Urologic Trauma Surgeon must not only be prepared to diagnose and treat the specific injury, but he must also be able to provide the support necessary so that the vital functions are optimally preserved. The first two chapters deal with general supportive aspects of the care of the trauma patient and the remaining five chapters with the etiology, classification, diagnosis, treatment and complications of specific genitourinary tract injuries. Diagnostic roentgenographs and surgical procedures are illustrated, and it is our hope that the illustrations and text will provide the proper foundation for the complete care of the trauma patient whose injury involves the urologic system.

W. SCOTT MCDOUGAL, M.D.
LESTER PERSKY, M.D.

Contents

1

Care of the Trauma Patient

INITIAL CARE

The principles of initial management for the urologic trauma patient are identical to those for any injured individual. There is a tendency, however, for the specialist to focus on his particular area of expertise and thereby inadvertently overlook aspects of immediate care which are essential to the patient's survival. Therefore, the urologist must determine that the following aspects of care have been instituted before proceeding to the specific urologic evaluation.

The patient's airway must be clear and respiratory exchange unimpeded. (The management of patients with respiratory insufficiency is described subsequently.) Hemorrhage must be controlled and a large bore intravenous (IV) catheter should be positioned in such a way as to preclude the possibility of an injured vessel lying between the IV entrance site and the heart. For example, it is inappropriate to place a single IV in the femoral vein in a patient who has sustained abdominal trauma. Should the vena cava be injured, the infusate will not reach the heart where it is needed but rather enter the abdomen. Multiple IV's, one of which is centrally placed, are indicated when major vascular injuries have been sustained or when blood loss is considerable. Blood pressure must be maintained, initially with infusions of crystalloid, colloid, or stroma-free hemoglobin and ultimately with type-specific blood, should prior blood loss warrant. A baseline set of laboratory data should be obtained, including a complete blood count, serum electrolytes, glucose, blood urea nitrogen, creatinine, and amylase. Arterial blood gases are obtained when indicated. The patient should also be typed and cross-matched for blood.

The nature of the patient's immunization status for tetanus must be determined. Adult patients are immunologically competent when they have received at least three injections of toxoid, the last within 10 years of the current injury. Children under 7 years of age require four injections of toxoid followed by a fifth at age 4 to 6 years. They are immunologically protected thereafter and require a booster injection at 10 year intervals. Patients who have been fully immunized and who have received a booster within the last 10 years do not require a toxoid injection, provided the wound is not at high risk for tetanus. In those patients whose wounds are prone to *Clostridium tetani* infestation, 0.5 cc of tetanus toxoid is given if their last booster was obtained more than 5 years previously. If the patient has received two or more injections of toxoid, but the last dose was given more than 10 years ago, 0.5 cc tetanus toxoid is administered. All others who have wounds which could harbor *C. tetani* should be given 0.5 cc tetanus toxoid plus 250 units or more of tetanus immune globulin injected at a site distant from the toxoid injection.[1]

A history and physical examination including a neurologic exam must also be obtained. The gravity of the patient's condition dictates the nature of the history and physical, but if initially brief, it must be thorough with respect to the nature and extent of injury as well as with respect to the vital functions provided by the respiratory, neurologic, and cardiovascular systems. As early as is consistent with good care, a complete history and physical must be obtained—a point often overlooked in the care of trauma patients. Finally, fractures should be splinted, and when indicated, a nasogastric tube inserted. It is important to note that the placement of a Foley catheter is not part of the initial management and is performed only after the lower genitourinary tract has been carefully examined (vide infra).

THE UROLOGIC EXAMINATION

Evaluation of the traumatized patient requires a systematic approach. A thorough history is obtained which must include questions directed at determining the presence of bleeding tendencies, prior hematuria, congenital or acquired genitourinary disease, micturition difficulties, urinary tract infections, prior genitourinary trauma, and operative procedures. The physical examination includes observation of the abdomen and flank for symmetry, palpation of the flanks and suprapubic areas for masses, rib fractures, or tenderness, palpation of the pelvic bony structure for fractures, observation of the external genitalia, perineum, and urethral meatus for blood or echymoses, palpation of the penile shaft and testes for tenderness, and rectal examination of the prostate for tenderness and position. Radiographic examination follows the history and physical examination.

The sequence in which diagnostic roentgenographs of the genitourinary system should be obtained proceeds from the urethra to kidney, eliminating those studies which are unnecessary as determined by the history and physical examination. A urethrogram is performed, preferably under fluoroscopic control, by placing a 10 to 14 French Foley catheter in the fossa navicularis and inflating the balloon until a snug fit is obtained. Ten cc of 10 to 20% water soluble radiocontrast is injected. If flouroscopy is not available, the film should be exposed during the injection, for if postinjection films are obtained, coaptation of the urethral walls may prevent visualization of the entire structure. If the urethra is uninjured, a Foley catheter is introduced into the bladder through which 300 to 400 cc of contrast is allowed to flow by gravity. Following the radiograph of the full bladder, the contrast is completely drained from the bladder and another roentgenogram obtained. Some advocate washing the bladder with saline to assure complete removal of all intravesical radiocontrast. The postdrainage film will reduce the chance of missing a small posterior extravasation which might be hidden by the dye-distended bladder. Finally, an IV pyelogram is obtained. Angiography, ultrasonography, and computerized axial tomography follow when indicated.

When several disciplines are involved in the care of the multiply injured patient, the efforts of all must be coordinated into a sequence which is most advantageous for the individual patient. The order in which injuries are repaired is dependent upon priorities of care which are determined by the life-threatening nature of the injury as well as its potential for prolonged morbidity. Moreover, the Urologic Trauma Surgeon must be prepared to adapt his therapy according to the overall needs of the patient. For example, a multiply injured patient with a posterior urethral disruption who is unstable due to other traumatic injuries should not be subjected to a primary repair even though the surgeon may feel this to be optimal therapy for that particular genitourinary injury. Under these circumstances, a suprapubic cystostomy is preferred since it results in little blood loss and requires little operative time, thereby allowing the major thrust of therapy to be directed at the life-threatening injury.

The general care of trauma patients requires that the Urologic Surgeon be knowledgeable about respiratory, fluid and electrolyte, cardiovascular, renal, and blood transfusion complications. Therefore, a brief consideration of the most commonly encountered difficulties follows.

RESPIRATORY DYSFUNCTION

Respiratory Insufficiency

Inadequate ventilation in the post-traumatic and postoperative periods results in hypercapnia or hypoxemia, or both. The primary goal of therapy is to provide the patient with the capability of maintaining an arterial oxygen partial pressure of at least 60 mm Hg on an inspired oxygen content as close to room air as possible. In order to achieve this goal, oxygen delivered by nasal prongs, a face mask, or an endotracheal tube with respirator support may be required. There are, however, constraints to the amount of oxygen which can be delivered. Limitation of the amount may be a consequence of the device used for delivery; however, more commonly, the amount which can be safely delivered is limited by the fact that inhalation of high oxygen concentrations results in pulmonary toxicity. The hazards of high concentrations include suppression of the respiratory drive in patients with chronic lung disease, retrolental fibroplasia—primarily a disease of the newborn, but it has been described in adults—segmental atelectasis due to the greater solubility of oxygen compared to nitrogen, impairment of respiratory ciliary function, decrease in pulmonary surfactant, and direct injury to capillary endothelial cells.

The arterial carbon dioxide partial pressure which is normally 40 mm Hg is a primary indicator of the adequacy of ventilation. Common causes of hypercapnia include obstructive lung disease, adult respiratory distress syndrome, metabolic alkalosis, and respiratory depression due to sedation or central nervous system trauma. Hypocapnia may be a result of hypoxia, anxiety, pulmonary embolism, sepsis, and pulmonary insufficiency. Although an indicator of ventilatory adequacy, alteration of pCO_2 by itself is rarely an indication for respiratory support. Of more importance is the pO_2 which should be maintained above 60 mm Hg. A pO_2 less than 60 mm Hg requires a change in respiratory management. (The normal pO_2 for a particular patient breathing room air prior to injury may be estimated by subtracting one-half the individual's age from 100.)

If impending airway obstruction is not a problem, initial support of the pO_2 may be obtained by the use of nasal prongs or face masks. Humidified oxygen should be used when possible in order to prevent drying of the nasotracheal mucosa. Oxygen delivered by nasal prongs generally cannot provide an inspired concentration much above 50%. Even though humidified, high flows have a drying effect on the mucosa. Venturi masks provide constant flows of oxygen ranging between 24 and 40%, depending upon the mask. Partial rebreathing masks can deliver in excess of 80% oxygen; however, humidity cannot be added to the system.

On occasion, post-traumatic patients require endotracheal intubation—preferably by the nasotracheal route with a prestretched low pressure cuff—and respiratory support. The indications for intubation include: 1) the facilitation of pulmonary toilet, 2) the prevention of upper airway occlusion, 3) a protection against aspiration, and 4) the need for mechanical ventilation (Table 1.1). The requirement for mechanical ventilation is assessed by 1) vital capacity, 2) inspiratory force, 3) respiratory rate, 4) arterial oxygen content, and 5) work of breathing. Vital capacity or the volume of a maximal inspiration following a maximal expiration is normally 60 to 70 ml/kg body weight. If it is less than 15 ml/kg, ventilatory support is indicated. The inspiratory force or the amount of pressure one is able to generate against a closed airway is normally −75 to −100 cm H_2O. Patients who can achieve no more than −25 cm H_2O require mechanical support. The normal respiratory rate is 12 to 20/min.

Table 1.1
Indications for endotracheal intubation

Facilitation of pulmonary toilet
Prevention of upper airway occlusion
Protection against aspiration
Need for mechanical ventilation as determined by
1. A vital capacity less than 15 ml/kg body wt
2. An inspiratory force less than −25 cm H_2O
3. A respiratory rate in excess of 35/min.
4. A pO_2 less than 60 mm Hg despite high ambient O_2 concentrations
5. An excessive and prolonged increase in the work of breathing

A rate which exceeds 35 suggests the need for ventilatory assistance. The arterial oxygen partial pressure or pO_2 should exceed 60 mm Hg. If this cannot be accomplished by raising the oxygen content of inspired air through the use of face masks and nasal prongs, intubation should be performed. Severe intercostal retractions and a tracheal tug indicate an increased work of breathing and are forerunners of respiratory insufficiency.

Initially, the respirator is adjusted to deliver 12 to 15 ml/kg body weight at a frequency of 8 to 14 times per minute for the adult and 15 to 30 times per minute for the child. The inspired oxygen content or FIO_2 should be the lowest needed to maintain the pO_2 above 60 mm Hg (an FIO_2 of 40% is a good level to begin with, adjusting it upward or downward as required). Not only must blood gases be monitored, adjusting the respirator accordingly, but the circulatory status must be carefully followed, for on occasion institution of mechanical ventilation will cause a fall in the cardiac output with a resultant lowering of blood pressure. When the pO_2 cannot be maintained by an acceptable FIO_2 (less than 60%), the addition of positive end expiratory pressure (PEEP) may be helpful. This technique maintains a specified pressure at the end of each respiration rather than allowing end expiratory pressure to fall to zero. It is particularly useful in the adult respiratory distress syndrome (vide infra). Initially, 5 cm H_2O pressure is employed. If the desired response is not achieved, it is increased in increments of 5 cm H_2O, carefully monitoring the blood pressure for signs of a significant reduction in cardiac output. Usually, no more than 15 cm H_2O is required; however, on rare occasions as much as 25 cm H_2O may be needed. With the use of PEEP, pO_2 can be maintained at acceptable levels using reduced FIO_2's. Other advantages include a decrease in pulmonary shunting and an increase in functional residual capacity (FRC). A proposed advantage is that it drives pulmonary edema fluid from the alveoli and interstitium into the pulmonary capillaries. Its major disadvantages are a reduction in cardiac output and a diminished urine output. The latter effect is perhaps a result of an increased release of antidiuretic hormone.

One method of anticipating future respiratory difficulties as well as determining how the patient is progressing on the respirator is by sequentially determining the arterial oxygen gradient (A-aDO_2); this gradient is a sensitive indicator of early respiratory impairment. In order to calculate the A-aDO_2 gradient, the patient is placed on 100% oxygen for 20 to 30 minutes. Arterial blood gases are drawn and the barometric pressure recorded. The calculation is as follows: barometric pressure minus water vapor pressure (47 mm Hg) minus the partial pressure of alveolar CO_2 (because alveolar CO_2 rapidly equilibrates with arterial CO_2, the pCO_2 obtained from the blood gas analysis may be substituted). This quantity minus the pO_2 is equal to the arterial alveolar oxygen gradient. A normal value lies between 25 and 65. A value exceeding 450 suggests failure.

Ventilatory support is continued until the indications for its use no longer apply. If mechanical ventilation was the reason for intubation, the patient may be weaned from the respirator when the chest roentgenogram reveals no deterioration, the spontaneous respiratory rate is less than 30/

minute, PEEP is no longer required, the inspiratory force exceeds −25 cm H_2O, the vital capacity exceeds 15 ml/kg, and the pO_2 can be maintained above 60 mm Hg on a FIO_2 below 50%. The patient is weaned by placing him on a T-piece with humidified oxygen for 10 minutes of each hour. If the T-piece is tolerated, the time on it is gradually increased until the respirator is no longer required. The blood gases and the patient's respiratory effort must be carefully monitored both during weaning and following extubation.

Adult Respiratory Distress Syndrome

Acute post-traumatic pulmonary insufficiency (ARDS) occurs following major trauma, burns, hypoproteinemia or inadequate fluid resuscitation during shock, severe sepsis, pancreatitis or transplantation rejection crisis (antigen-antibody reaction). Following the initiating event, platelet microaggregates form in the pulmonary capillaries and injure the alveolar capillary endothelium. Vasoactive substances are released resulting in increased capillary permeability.[2] Peribronchiolar edema follows which causes an increase in small airway resistance and a reduction in lung compliance making aeration of the lungs difficult. Pulmonary shunting also occurs. The pO_2 falls and the pCO_2 rises, often despite increases in the FIO_2. The oxygen exchange ratio exceeds two (the oxygen exchange ratio is merely the alveolar arterial oxygen gradient divided by the pO_2). Clinically, the patient becomes dyspneic, tachypneic, and hypoxemic. There is a reduced FRC, reduced lung compliance, and often bilateral pulmonary infiltrates are present on the chest film. The syndrome should be suspected in the traumatized patient when the pO_2 falls despite efforts to increase the FIO_2. Treatment involves nasotracheal intubation and mechanical ventilation. PEEP is often necessary. If PEEP results in a reduced cardiac output, inotropic agents may be required in order to return blood pressure to acceptable levels. Isoproterenol, 0.25 to 1.0 μg/min, glucagon, 3 mg/hr, or digoxin are acceptable. The use of colloid to increase intravascular oncotic pressure and thereby draw fluid from the pulmonary perivascular space into the capillaries is controversial as is the use of steroids. Prophylactic antibiotics administered either by the parenteral route or by inhalation have little to recommend them. Infections are treated when they occur with the antibiotic to which the bacteria are sensitive.

Pulmonary Embolism

Pulmonary emboli may occur silently and be an incidental finding on a chest film, or they may suggest their presence by causing dyspnea, chest pain, hemoptysis, and rarely, when massive, circulatory collapse. On physical examination, the pulmonic portion of the second heart sound may be increased, a parasternal heave may occur, on occasion a friction rub can be heard, and the electrocardiogram often shows right heart strain as evidenced by right axis deviation. Chest x-ray, when positive, reveals a lucent area which lacks vascular markings. Later a wedge-shaped infiltrate develops. Pulmonary scans may be used to support the diagnosis but the definitive study is a pulmonary angiogram. Therapy is directed at identifying the source and treating it while simultaneously anticoagulating the patient, initially with a continuous heparin infusion. If the pulmonary embolus is large or saddle in type and is causing circulatory collapse which is unresponsive to supportive measures, a pulmonary embolectomy is indicated.

VOLUME AND ELECTROLYTE BALANCE

Immediate restoration of volume disturbances and electrolyte abnormalities in the traumatized patient is critical if subsequent cardiac, respiratory, neurologic, and renal dysfunction are to be avoided. Hemorrhage must be controlled and blood volume restored. Patients who have lost more than 1500 cc generally require transfusion. A blood loss equal to or exceeding 2% of the body weight results in shock and requires immediate restoration of blood volume. As a temporizing procedure, Ringer's lactate is infused initially at a rate sufficient to return blood pressure to acceptable levels or until such time as blood becomes available. Albumin, stroma-free hemoglobin, starch solutions, and dextran may also be used in limited amounts to maintain intravascular oncotic pressure until blood becomes available. Unfortunately, their excessive use in some shock states where capillary permeability is markedly altered may result in extravascular deposition with worsening of interstitial fluid accumulation. Moreover, infusion of large amounts of dextran alters hemostatic mechanisms and impure stroma-free hemoglobin may lead to acute renal failure.

Large losses are readily appreciated and immediate therapy straightforward; however, as resuscitation continues or when the injury has resulted in cardiac malfunction, sequential assessment of volume status is critical. Blood pressure and urine output are good guides but because of homeostatic mechanisms they provide no more than a gross estimate of volume replacement. The volume status can be more accurately assessed by central venous, pulmonary artery, and left atrial pressure measurements. Central venous pressure (CVP) is a good reflection of volume status provided there is no cardiac dysfunction. It may also be used to guide fluid therapy in those patients with cardiac abnormalities in which both ventricles are equally affected by the disease. Under these circumstances there is a good correlation between CVP and left ventricular filling pressure. Normal values range between 5 and 12 cm H_2O, depending upon the point of reference. We prefer to use the midaxillary line as the reference point since it is easily found and diminishes the chance of error arising from varying reference points when multiple observers perform the measurement. The important point is that CVP should be measured serially from the same reference point, thus allowing a dynamic accurate assessment of the adequacy of resuscitation. A patient with a low CVP should be given fluid until it is within the normal range.

When the CVP does not seem to correlate with blood pressure or in those patients with cardiac disease in which the two ventricles may be disproportionately affected, a more accurate guide is obtained by following pulmonary artery and left atrial pressures. These measurements are made using the Swan-Ganz catheter which is placed percutaneously into a major vein (jugular, subclavian, femoral) and directed into the right heart. The balloon on the tip of the catheter allows it to be floated through the ventricle into the pulmonary artery. Catheter position is determined by the pressure profile (Fig. 1.1) and final placement confirmed by x-ray (Fig. 1.2). The normal pulmonary artery pressure is 9 to 17 mm Hg. If the balloon is inflated in a branch of the pulmonary artery thereby occluding inflow, a pulmonary capillary wedge pressure (PCWP) is obtained which reflects left atrial pressure (normal 5 to 12 mm Hg). Thus, a low pulmonary artery pressure and PCWP indicate the need for volume replacement. If the PCWP is raised to 15 mm Hg without improvement in cardiac output, the need for an inotrope is suggested. With the thermal dilution Swan-Ganz catheters, cardiac output can also be measured. Once the patient's volume status has been restored to normal, maintenance fluid and electrolyte replacement must be calculated.

Maintenance Fluids

The amount of fluid which must be provided to the patient in order to maintain homeostasis is equivalent to the urine output plus insensible loss plus abnormal losses minus the water produced by the metabolism of fat, carbohydrate, and protein (Table 1.2). Each of these entities must be calculated for the individual patient if optimal fluid balance is to be achieved.

The amount of urine necessary to maintain proper balance is dictated by the physiologic limits of the kidney for solute and water excretion. In resting man, the products of normal metabolism produce a solute load which requires a minimum of 400 to 600 cc of urine for excretion. Traumatized and critically ill patients are often hypermetabolic and produce increased solute loads, thereby necessitating slightly greater amounts of urine production. On the other hand, excessive output may lead to a washout of the renal medullary osmotic gradient resulting in

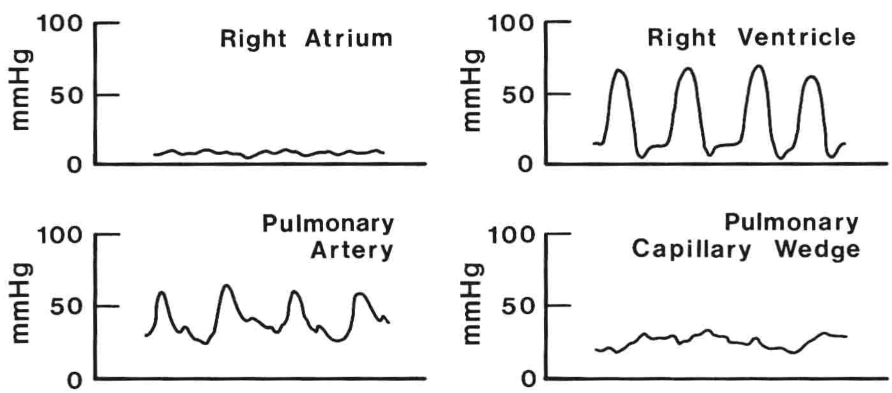

Figure 1.1. Pressure tracings of the right atrium, right ventricle, pulmonary artery, and pulmonary capillary wedge. As the Swan-Ganz catheter is passed through the heart into the pulmonary artery, its position is determined by the pressure tracing and final placement confirmed radiographically.

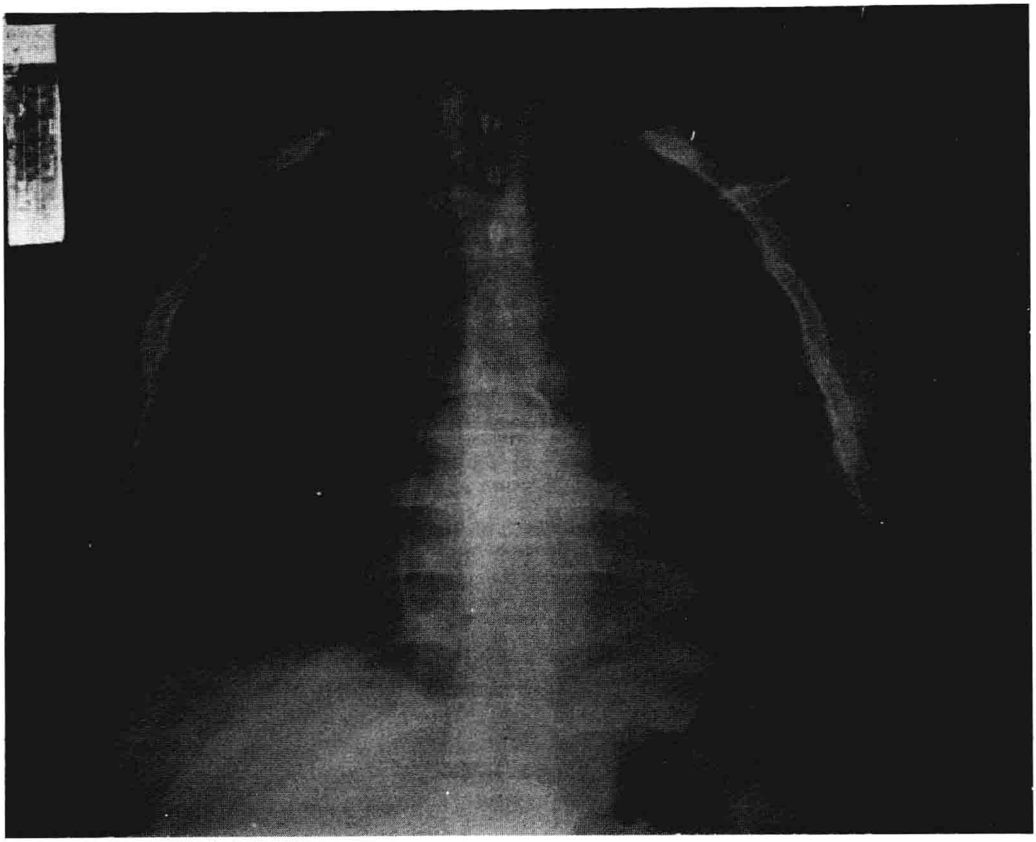

Figure 1.2. Roentgenogram of a Swan-Ganz catheter in position.

Table 1.2
Summary of formulas for fluid administration

Basic fluid requirement	= (U.O. + Insens. + Abn. Loss) − H_2O Met.
Urine Output (U.O.)	= 30-50 cc/hr, adult or 20-40 cc/kg/24 hrs, child
Insensible loss (Insens.)	= 10-15 cc/kg/24 hrs, adult or 45 cc/100 kcal, child
Abnormal loss (Abn. Loss)	= measured external or estimated third space losses
Water of Metabolism (H_2O Met.)	= 10% × (25 × kg body wt), adult or 10% × (kcal metabolized), child

impaired concentrating capabilities of the kidney. The fluid intake required to produce large urine outputs may also result in fluid retention and vascular overload. Therefore, there are limits between which urine output should be maintained. The adult kidney is most efficient in maintaining balance when fluid intake is sufficient to produce a urine output of 800 to 1200 cc/day or 30 to 50 cc/hr. In children, urine output should be maintained between 20 and 40 cc/kg body weight/day. Under