A 62-year-old woman developed shock immediately after the insertion of a right-sided chest tube. A chest roentgenogram showed the chest tube to be overlying the heart and possibly compressing the right ventricle. An animal model was developed to replicate this clinical situation. Using a domestic goat model pulmonary artery, peripheral arterial catheters were inserted along with a right sided chest tube placed to suction. A second chest tube guided by a flexible fiberoptic bronchoscope placed within its lumen was positioned between the right ventricle and the sternum of the animals. Thirteen paired measurements in three goats (average of 4.3 measurements per animal) of cardiac output, heart rate, and mean arterial blood pressure were made at baseline and after chest tube placement over the right ventricle. The data were analyzed using a paired t test statistic. Compared with baseline measurements, there was a significant decrease in cardiac output (p<0.0001) and mean arterial pressure (p<0.0001) as well as an increase in heart rate (p=0.0056) after placement of the chest tube across the right ventricle. We conclude that a misplaced chest tube compressing the right ventricle can impede cardiac output and lead to a low cardiac output state. Physicians inserting chest tubes in patients should be aware of this potential complication as it is easily treated by withdrawal of the chest tube.  

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Cardiogenic shock due to chest tube compression of the right ventricle has not been previously described (to our knowledge). A case report and an animal model are presented that highlight the potential morbidity that can result from this previously unreported complication.

**CASE REPORT**

A 62-year-old woman was diagnosed as having Berger's disease three months prior to hospital admission. She was treated with 20 mg of prednisone taken daily. Two days prior to hospital admission, she developed a productive cough associated with chills and fevers.

A chest roentgenogram showed bilateral patchy infiltrates along with a cavity in the right lower lobe. The patient was transferred to our institution for care. On arrival, she appeared to be in severe pulmonary distress and was electively intubated and placed on mechanical ventilation.

After approximately 20 minutes of mechanical ventilation, the patient became acutely agitated and cyanotic. A chest roentgenogram showed evidence of a new right pneumothorax. A 28-French closed thoracostomy tube was placed in the sixth intercostal space in the midaxillary line. The patient became more relaxed and easier to ventilate after chest tube placement.

On the following hospital day, computed tomography of the chest demonstrated a cavity in the right lower lobe surrounded by consolidated lung consistent with a lung abscess. The abscess appeared to be abutting against the visceral pleura. Pleural fluid cultures and cultures of sputum were positive for *Proteus mirabilis*. The computed tomogram of the thorax also showed the chest tube to be within the major fissure of the right lung.

A new 28-French chest tube was inserted in the seventh intercostal space just posterior to the anterior axillary line to allow for more complete drainage of the pleural space. The original chest tube was withdrawn. Following the placement of the new chest tube, the patient became agitated and hypotensive. Her blood pressure dropped from 110/65 mm Hg to a systolic blood pressure of 60 to 65 mm Hg and her heart rate increased from 98 to 125 beats per minute.

An urgent chest roentgenogram was obtained (Fig 1) that showed the newly placed chest tube to be crossing the midline of the thorax and bending on itself. There was no evidence of tension pneumothorax. The chest tube was withdrawn producing almost immediate reversal of the shock state. The patient's vital signs returned to their previous baseline values. A subsequent new chest tube was placed with chest roentgenograms showing it to be in proper position. The patient died one week later from the complications of sepsis and multiple systems organ failure.

**MATERIALS AND METHODS**

**Preparation of the Animal**

Three adult goats were used and prepared for the experimental study as illustrated (Fig 2). Adult goats were chosen for their size allowing easy placement of thoracostomy tubes within the goat's thoracic cavity. In addition, the gross anatomy of the goat's thorax and mediastinum is generally similar to that of man allowing comparison to be made between the animal model and man. The goats underwent routine laboratory screening and quarantine procedures under the supervision of a veterinarian and trained animal...
care personnel. All care and use procedures performed on these animals were in accordance with the American Association for Accreditation of Laboratory Animal Care (AAALAC) standards. The protocol was approved by the Fitzsimons Army Medical Center (FAMC) Laboratory Animal Use Committee prior to beginning the study. FAMC is fully accredited by AAALAC.

Each animal was fasted for 24 hours and water was withheld for 12 hours prior to the experiment. The goats were anesthetized with tiletamine hydrochloride (Tilazol) and zolazepam hydrochloride (A.H. Reckitt Co., Richmond, VA) 15 mg/kg given intravenously. The animals were then orally intubated by the veterinarian using an endotracheal tube.

The lateral aspect of the animal’s right thorax and medial aspect of the right hind leg were then sheared. The goats were then positioned in the supine position on the operating table and anesthesia was maintained with the inhalational agent, isoflurane. The fractional inspired oxygen concentration (F\textsubscript{I\textsubscript{O}}\textsubscript{2}) was adjusted to maintain arterial oxygen saturations greater than 92 percent using a pulse oximeter (Ohmeda model 3710, Ohmeda, Madison, WI).

A surgical cutdown was performed in the right inguinal region using sterile technique, and the right femoral vein and artery were isolated. A 22-gauge arterial catheter (Arrow International, Inc., Reading, PA) was secured in the right femoral artery. A pulmonary artery catheter (93A-131-7F American Edwards Laboratories, Irvine, CA) was then placed in the right femoral vein and floated into the pulmonary artery. Location of the catheter tip in the pulmonary artery was assessed using pressure waveform analysis initially and confirmed by inspection and palpation of the catheter tip in the pulmonary artery at the termination of the protocol.

A 32-French chest tube was inserted between the seventh and eighth ribs of the right lateral thorax. This chest tube was directed posterior to the right lung and placed on suction to maintain lung expansion. A second 32-French right angle tube was then inserted between the fifth and sixth ribs of the right lateral thorax. A right angle chest tube was chosen to allow more direct comparison to the clinical situation that occurred in our patient with the chest tube forming an angle after bending on itself. A 32-French chest tube size was chosen to optimize the compressive effects of the chest tube on the right ventricle for purposes of this protocol. Positioning of the right angle chest tube was assessed with a fiberoptic bronchoscope (model BRO-YL2, Fujion Inc, Wayne, N.J.) placed within its lumen to ensure that it was positioned up against the heart. The chest tubes were placed in ice water for 10 s prior to insertion to allow for a more rigid tube that could be more easily positioned.

**Measurements**

Prior to the experimental trials on each animal, the monitoring equipment used to measure arterial pressures was zeroed and calibrated in accordance with established standards and recommendations as set forth by clinical experience and by the manufacturers of the monitoring equipment. A trained critical care nurse made

![Figure 1. Chest roentgenogram showing the chest tube compressing the right ventricle.](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21627/)
all measurements of cardiac output and pressure recordings.

Electrocardiogram, heart rate, and systemic arterial pressures were monitored and recorded (using a Marquette Electronics Monitoring Unit, series 7010 RA Control Unit, Marquette Electronics Inc, Orange, CA). Cardiac output was obtained by injecting 5 ml of 5 percent dextrose in water (cooled to a temperature <15°C) through the proximal port of the pulmonary artery catheter. The injectate was administered at end expiration and injected in less than 4 s to improve the reproducibility of the data. The average of three evenly spaced determinations was used as the measure for the cardiac output. The cardiac outputs were measured by the thermodilution method with a computer (Oximetry 3 SO2 CO Computer, Abbott Critical Care Systems SN:30038, Mountainview, CA).

For each trial of the experiment, baseline blood pressure, heart rate, and cardiac output measurements were obtained after ensuring stable vital signs for 5 minutes with a less than 10 mm Hg change in mean blood pressure and 10 beat per minute fluctuation in heart rate. After gathering these baseline data, the second chest tube was placed anterior to the heart between the right ventricle and the sternum under guidance by the bronchoscope located within the lumen of the chest tube.

Repeated measurements of the systemic arterial pressures, cardiac output, and heart rate were obtained and compared with the baseline data. Measurements were taken after chest tube compression of the right ventricle only after observing stabilization of the animal’s new vital signs for 5 minutes with a less than 10 mm Hg change in mean arterial blood pressure and 10 beat per minute fluctuation in heart rate. The second chest tube was then removed from the mediastium and withdrawn from the chest. The animal was then allowed to reequilibrate to a new baseline for at least 5 minutes prior to the next experimental trial.

**Statistics**

Measurements obtained after placement of the second chest tube

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**Figure 3.** Cardiac output at baseline and after chest tube placement (mean ± SD are shown).

**Figure 4.** Mean arterial blood pressure measurements (mean ± SD are shown).
increase in heart rate along with the significant decrease in cardiac output. Impaired right ventricular filling due to the compressive effects of the chest tube on the right ventricle is the probable mechanism for this decrease in stroke volume. Similar hemodynamic effects from a chest tube compressing the left ventricle would be expected; however, this was not examined in our patient or our animal model.

This mechanism of producing cardiac dysfunction by the mechanical impedance of ventricular filling is well documented in other clinical situations where cardiac compression or limitation of cardiac expansion occurs. Examples of these clinical situations include the following: pericardial tamponade, constrictive pericarditis, the auto-PEEP (intrinsic-PEEP) phenomenon, tension pneumothorax, and the closing of the chest after median sternotomy in patients with hyperinflated lungs (also possibly due to auto-PEEP).

In conclusion, we have demonstrated that significant cardiac dysfunction can be produced by a misplaced chest tube compressing the right ventricle. The cause of this dysfunction appears to be impairment of right ventricular filling that subsequently leads to a decrease in the cardiac stroke volume.

Our results are limited to the use of a right angle chest tube that would be expected to produce more compression of the right ventricle compared with a straight tube. This may explain the rarity of this complication, as straight chest tubes normally do not bend on themselves. In both our case report and our animal model, the compressive effects of the chest tube on the right ventricle appeared to occur immediately after placement of the tube in the anterior mediastinum. These situations occurred without suction being applied through the chest tubes. The role of suction was not otherwise addressed by this study.

Although this complication of chest tube insertion appears to be rare, as it has not been previously reported (to our knowledge), physicians treating patients who require chest tube placement need to be aware of this potential problem. When a patient is encountered who develops significant hypotension or a shock state after chest tube insertion, then consideration of this entity and withdrawal of the chest tube should be entertained if other causes of the shock state are excluded.

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