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CASE REPORT

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Fatal Venous Air Embolism Following Intravenous Infusion*

ABSTRACT: Venous air embolism has been reported as a complication of invasive diagnostic and therapeutic procedures or accidental trauma. Little is known about the incidence of air embolism after minimal intravenous manipulations such as the insertion of a peripheral intravenous cannula. Only when large amounts of air sufficient enough to block the cardiovascular system enter, the patient develops symptoms and signs of severe neurological injury, cardiovascular collapse, or death. The dead body of a 14-year-old boy was brought for postmortem examination with allegations of death from negligence during treatment. He was treated for pain in the abdomen in a hospital by attendants in telephonic consultation with a medical practitioner. Following intravenous infusions, the boy died suddenly in respiratory distress. Gross findings indicated the death to be from venous air embolism. Chemical analysis, histopathology, and microbiology ruled out other causes of death. Dilemmas of the case with difficulties in diagnosis are being presented herewith.

KEYWORDS: forensic science, forensic pathology, intravenous infusion, respiratory distress, frothy blood, venous air embolism

Venous air embolism (VAE) is an entity where circulation gets blocked by entry of air through the venous side. The entered air after reaching the right ventricle is not pumped forward as it is compressible. VAE produces several effects. A large, rapidly entrained bolus of air can fill the right atrium with air and cause an air lock which leads to obstruction of the right ventricular outflow tract, decreased venous return, and decreased cardiac output. Myocardial and cerebral ischemia soon follows (1). It is said that death is usually immediate but can be delayed up to 2 h (2). The factors that determine the subsequent morbidity and mortality in VAE include the rate of air entrainment, the volume of air introduced, and the position of the patient at the time of the embolism (3).

The amount of air needed to result in fatal venous embolism has been hotly debated for years with estimates varying from 10 to 480 mL (4). If the volume of the right side of the heart is believed to be the minimum space to be filled, about 100 mL can be accepted as a reasonable fatal volume (2). Although classical teaching states that more than 5 mL/kg of air (IV) is required for significant injury (including shock and cardiac arrest), patient complications secondary to as little as 20 mL of air (the length of an unprimed IV infusion set) have been reported (3).

The causes of VAE can be surgical procedures, especially neurosurgical procedures performed in the upright, sitting position or iatrogenic creation of a pressure gradient for air entry or mechanical insufflations and infusion or positive-pressure ventilation, which can occur during mechanical ventilation and SCUBA diving. Finally, blunt and penetrating trauma to the chest, abdomen, neck, and face also can lead to the entry of air and ultimately to VAE (3).

Venous air embolism has been reported as a complication of invasive diagnostic and therapeutic procedures or accidental trauma. Little is known about the incidence of air embolism after minimal intravenous manipulations such as the insertion of a peripheral intravenous cannula (5).

One of the instances where sufficient air can gain access into the venous side is during intravenous infusion. The risk is more when rigid glass bottles are used wherein the vent tube allows air to enter the connecting tube if the bottle is allowed to empty completely. With flexible, collapsible bottles, the danger is less (2).

Fatal intravenous air embolism following intravenous infusion is a known but a lesser heard entity. In this part of the world such deaths have not been reported. The reasons may be many but one of the important reasons the authors feel is the difficulty in diagnosis of such cases. Pathological autopsies are not routine here, only medicolegal autopsies are performed. In the case of deaths in hospital during treatment, the case is converted to a medicolegal one only on the complaint of the relatives alleging negligence in the treatment. The investigating officers are ill-trained in investigation of hospital deaths. Many important evidences are lost due to ignorance regarding collection of materials used during treatment from the hospital, delay in transit of the body to the mortuary, nonconsultation with forensic expert, and many more. As a result, pathological findings along with circumstantial evidences are lost posing difficulty in diagnosis. The same problems happened with this case and despite all the limitations the autopsy surgeon came to the conclusion regarding the cause of death.

Case

The dead body of a 14-year-old boy was brought for postmortem examination to the mortuary of New Civil Hospital, Surat at around 4:30 PM on May 31, 2007. Along with the prerequisite documents

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for postmortem examination (requisition, copy of inquest report, and dead body challan [invoice statement]), the investigating officer submitted a single sheet treatment record issued by the hospital where the boy had been admitted and died. The case was converted as medicolegal after the parents of the deceased lodged a complaint with the police alleging negligence in the treatment, resulting in the death of the boy. The police constable accompanying the dead body had no first-hand information regarding the case, hence the investigating officer was called for.

Parents of the deceased boy gave history that at 5 AM in the morning the boy was taken to a private medical practitioner with chief complaint of nonspecific pain in the abdomen on the left side for the past 2 h. He was advised admission and accordingly, at about 6 AM, the boy was admitted to a local multispecialty private hospital. As part of treatment, two bottles of infusions (one after another) and an intramuscular injection was given over the left gluteal. No other treatment was given and no investigation was advised. The infusions were run for about 3.5 h. At around 10 AM, the boy had respiratory distress and died suddenly. The relatives, alleging negligence of the doctor, lodged a police complaint. According to the relatives, the hospital attendants on duty had called the doctor on the telephone and started the treatment on telephonic advice. The hospital attendants themselves had started the infusions. Even on repeated requests, no doctor ever visited the boy at any time during the period of admission in the hospital. The doctor on duty had arrived along with the police after the complaint was lodged at around 12:30 PM.

The single sheet treatment record issued by the hospital stated that an intravenous injection of pantoprazole 40 mg in 100 mL of normal saline and ringer lactate infusion was given. Along with it an intramuscular injection of Cyclopam® (dicyclomine hydrochloride, Indoco Remedies Ltd., Mumbai, Maharashtra, India), 10 mg was given over the left gluteal region. The duty doctor had certified death on a plain sheet of paper, with "acute cardio-respiratory arrest (pain in abdomen under investigation)" given as cause of death. The time of death mentioned on the certificate was 12:15 PM. But the dead body challan submitted by the police mentioned the time of reporting of death at 10:10 AM, leaving a question mark on time of death stated by the duty doctor.

The investigating officer could not be contacted. The postmortem could not be delayed or postponed for the next day because of the hue and cry raised by the relatives. Hence the postmortem was started at 4:45 PM (about 6.5 h after death) with the available history and treatment summary.

On external examination, an intravenous infusion catheter was present *in situ* at the back of the left wrist. The body was nearly at room temperature. Rigor mortis was appreciable all over the body—developed in the upper parts and developing in the lower parts; lividity was well developed over posterior aspects of the body, purplish-red in color and fixed. The face was swollen with subcutaneous crepitations being palpable over face, neck, upper part of front of both sides of chest, and parts of both shoulders and upper arms. There was bluish discoloration of lips. Blisters with epidermal peeling were present over the left gluteal region. The teeth were intact and the oral cavity and pharynx showed no signs of an endotracheal intubation.

On internal examination, abdominal examination was essentially negative. The chest cavity was opened next. After reflecting the layers of the chest, the sternal plate was dissected and the internal mammary vessels ligated before removal of the sternal plate. The pericardial sac was inspected and the cavity found to contain 50 mL of clear reddish fluid. The major blood vessels were inspected and were clamped *in situ* before sectioning and the heart en bloc (heart with the attached blood vessels) was transferred to a basin filled with water. The right side of the heart was then incised under water which was found to be filled with copious fine red frothy blood. Similar frothy blood was also found in the superior vena cava, the neck veins, and inferior vena cava. There was minimal frothy blood in the pulmonary artery whereas the left side of the heart and aorta was nearly empty with no frothy blood inside them.

All internal organs were found congested except the lungs. The pleural cavities contained 100 mL of clear reddish fluid each. Characteristic findings were present in the chest cavity wherein the lungs were devoid of any blood and cut sections revealed only minimal whitish froth. The peritoneal cavity also contained 150 mL of reddish fluid. Apart from the above there was no significant finding at autopsy, leaving the cause of pain in abdomen still in question.

Viscera were sent for chemical analysis (whole stomach and piece of small intestine with contents, piece of liver and half of each kidney, and blood); tissues from all the organs (whole heart, both lungs, liver, half of each kidney, whole spleen, piece of each cerebral hemisphere, both cerebellar hemispheres with brain stem, whole pancreas, piece of left psoas muscle, and pieces of small and large intestine) were taken for histopathology and splenic swab was collected taking sterile precautions for microbiological examination. The cause of death was initially kept pending for laboratory reports.

The laboratory investigations were essentially negative. Chemical analyzers report showed presence of dicyclomine in samples of stomach, small intestine, blood, liver, and kidneys. Microbiology examination of splenic swab was negative. Histopathological examination revealed mononuclear infiltration in samples of lungs and liver, necrosis of mucosal lining with submucosa showing mononuclear cell infiltration in samples of small and large intestine, and no remarkable pathology in samples of heart, kidneys, spleen, pancreas, psoas muscle, and brain. Keeping in mind the history of the case and gross postmortem findings, the cause of death was given as VAE following intravenous infusion.

Discussion

In the present case, a meticulous autopsy was performed. There was no macroscopic demonstrable lesion to explain pain in abdomen and sudden death in a 14-year-old boy. No positive finding was observed except for features suggestive of air embolism. Infection was ruled out from negative splenic swab. Histopathology report had only one positive finding—necrosis of mucosal lining with mononuclear cell infiltration in sections of small and large intestine. Absence of polymorphs meant no acute infection. Presence of mononuclear cells cannot be attributed for the abdominal pain as it is a nonsignificant finding. Necrosis could be explained as a terminal entity in event of deficient blood supply during development of fatal air embolism. After going through literature on dicyclomine extensively, no reference regarding excretion of dicyclomine back into stomach and small intestine following intravenous injection was found; moreover detailed history did not reveal the boy being given any oral dose of the drug too, thus questioning the authenticity of the chemical analyzer's report. The drug dicyclomine is not known to produce anaphylaxis (6) and the body also did not show any such sign. The boy died about 3.5 h after medication and hence possibility of anaphylaxis was ruled out. The given dose of 10 mg did not result in overdose. The drug is known to increase body heat which might be the reason for peeling of skin over the left gluteal region where it was given intramuscularly. The postmortem examination was performed within 6 h of death. The authors have experience of thousands of postmortems and have not found dead

bodies in Surat (Gujarat, India) to undergo decomposition in such a short period keeping in mind the climatic conditions of the region.

It was not known whether the relatives of the boy in their anxiety to afford immediate relief caused any pressure on the intravenous fluid bottle so as to force the infusion. However, it has been recorded that while using flexible, collapsible plastic infusion bottles, if the bottle is allowed to empty completely, air enters the tubing and on connecting a new bottle, the subsequent flow drives all the air into the circulation (2).

An unusual complication of intravenous infusion has been reported in a 4-week-old baby that developed acute cardiopulmonary distress because of air embolism caused by improper preparation of peripheral intravenous set. The estimated amount of infused air was 12 mL (*c.* 3.5 mL/kg). The infant recovered promptly after short supportive treatment (7).

To diagnose air embolism, a pre-autopsy chest radiograph must be taken which is by far the best way of demonstrating air in sufficient quantities to be fatal. If air embolism substantial enough to have caused death is present, frothy blood oozing from the ventricular lumen, almost invariably in the right, will be quite evident. If this is apparent, however, it will almost certainly already have been seen on the pre-autopsy radiograph (2).

A pre-autopsy chest radiograph is not a routine procedure while conducting postmortems here in India. Moreover, suspicion of air embolism in this case as one of the possibilities was aroused only after the dead body was opened. Hence a pre-autopsy chest radiograph was not available in this case.

Bajanowski et al. (8,9) have advocated analysis of gas originating from heart ventricles by gas chromatography and results assessed according to the criteria defined by Pierucci and Gherson (10,11) before diagnosis of air embolism is justified.

In the present case, air samples from ventricles were not subjected to analysis because of lack of such analytical facilities. With all the above facts—the positive findings in the given case of history of intravenous infusion by unqualified attendants, sudden death after about 3.5 h following respiratory distress, presence of fine frothy blood in the right side of the heart and draining major vessels, subcutaneous emphysema over upper parts of the body and negative findings with regards to any other cause of death—the cause of death in the given case was given as ''air embolism following intravenous infusion.''

Venous air embolism is a distinct possibility in all cases where intravenous infusion is given. In fact, any needle placed in the venous system carries the risk of causing air embolism. Such incidences can, however, be minimized if the doctor is aware of its possibility and exerts utmost care while administering intravenous fluids.

Again, while conducting autopsies on bodies of persons suspected to have died due to air embolism, the technique of dissection and opening the heart should be strictly followed. Otherwise there could be scope for misinterpreting the possible artifacts as air embolism.

The case also throws up a debate on whether such deaths could be labeled as deaths due to negligence or not, keeping in mind the treatment provided over the telephone and no evidence of a medical practitioner supervising treatment, etc.

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