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CASE REPORT

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Mechanism of fatal air embolism after gastrointestinal endoscopy

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Abstract Although venous air embolism is a known complication in medical practice in general, only a single case of upper gastrointestinal endoscopy complicated by venous air embolism with consecutive acute cardiovascular failure has so far been described in literature. Here we show that gastroscopy may be accompanied by massive, i.e. fatal venous air embolism. If a vessel in the gastrointestinal tract is exposed but does not collapse (in the case of a gastric ulcer, for example) air insufflated under pressure by the gastroscope may lead to a fatal air embolism. Our tests using a commercial gastroscope revealed that an overpressure of up to 43 kPa (kiloPascals) is reached without the rinsing function while an overpressure of up to 45 kPa is measured if the rinsing function is operated simultaneously. The maximum flow rates without resistance were 100 ml/min for rinsing liquid (purified water) and 2000 ml/min for air. Our results suggest that air insufflation by the gastroscope may result in a critical air embolism within very few seconds on condition that a connection with the vascular system exists. However, this complication is extremely rarely encountered. We propose that CO_2 should be administered in place of air or alternatively the maximum pressure should be considerably reduced to avoid a fatal outcome in routinely performed gastroscopical examinations.

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Introduction

Ever since the development of fiberscopes with flexible tips, endoscopy of the upper gastrointestinal tract has become a routine medical examination. The procedure is generally carried out using a forward-viewing endoscope (gastroduodenoscopy) whereas side-viewing instruments are used for endoscopic retrograde cholangiopancreatography (ERCP) [1].

We wanted to get a detailed insight into fatal complications accompanying gastroscopy based on the following case:

Case report

A 56-year-old man had suffered from epigastric pain and was admitted for gastroscopy. According to his clinical records a perforated gastric ulcer was surgically treated 13 years ago. During endoscopic examination a marked lividity of the bulbar mucosa was noted. The patient suddenly became restless, cardiac arrest occurred and the cardiopulmonary resuscitation performed immediately was unsuccessful. By echocardiography air bubbles were seen but were found to be clinically insignificant.

Forensic necropsy revealed that massive air embolism in the right atrium and the right ventricle was the cause of death. The foramen ovale was closed and the left heart was filled with blood. A deep ulcer 6 mm in diameter was detected in the mucosa of the indurated and narrow pyloric canal. At the base of the ulcer there was an open blood vessel identified as the right gastric vein (Fig. 1). Other pathology findings which could be responsible for the sudden death were not found [2].

Materials and methods

In order to investigate the risks involved in gastroscopic examination we used a standard gastroscope of the same type used in the case described. To determine the maximum pressure that occurs during insufflation of air by the gastroscope, air was pumped into a 1-liter container without an air outlet. The pressures were recorded using a pressure measuring probe with a pressure sensi-

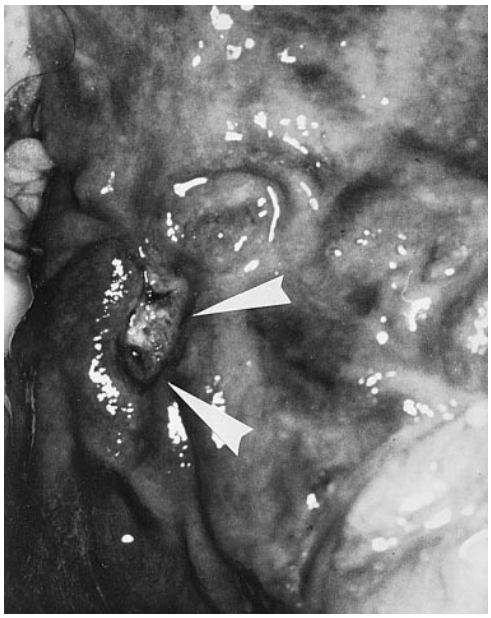

Fig. 1 Ventricular ulcer with eroded vessel (right gastric vein) at the base

tivity of 2 $\mu V \cdot V^{-1} \cdot mmHg^{-1}$ up to 1000 kPa (kiloPascals) from 20 °C to 40 °C. We then used a measuring cylinder to determine the maximum flow rates for air and fluid.

Results

Pressure measurements

When air was pumped into the air-filled 1-liter container using the gastrocope a maximum pressure of 43 kPa (kiloPascals) built up within a few seconds. Pumping air into a container filled with fluid (1 liter) also resulted in pressures of 43 kPa . When the rinsing function was used in addition the maximum pressure recorded was 45 kPa and was maintained for the entire duration of pumping. The mean flow rate for fluid (purified water) was 100 ml/min and for air 2000 ml/min.

Discussion

According to a survey conducted by the American Society for Gastrointestinal Endoscopy (ASGE) 70 instances of perforation, 63 instances of hemorrhage, 129 cardiopulmonary responses and 17 cases of infection occurred in a total of 211410 endoscopic examinations of the upper gastrointestinal tract. This is equivalent to 279 complications or a complication rate of 1.32 per 1000 examinations and 13 patients died from complications, i.e. 0.0061% [3].

A British study of 24000 endoscopic examinations of the upper gastrointestinal tract described 77 instances of complications including 5 of cardiovascular origin and a total of 6 cases had a fatal outcome. This corresponds to a complication rate of 3.2 per 1000 cases and a mortality rate of 0.025% [4].

In their assessment of the hazards of esophagogastroduodenoscopy, Ottenjan and Frimberger [1] and Habr-Gama and Waye [5] described hemorrhage, perforation and cardiopulmonary responses as relatively frequent complications [1, 5]. The authors did not observe air embolism caused by endoscopic examination.

Several large-scale studies [1, 3–5] reflect the general incidence of complications related to gastroscopy. Cardiovascular or cardiopulmonary responses are mentioned in a number of cases. The potential influence of liquid imbibition or insufflation of air or gas is not discussed in these studies.

Fatal air embolism caused by gastrointestinal endoscopy was first described by Lowdon and Tidmore in a case report in 1988 [6]. A 4-month-old girl who had been subjected to the Kasai procedure (hepatoportoenterostomy) at the age of 5 weeks underwent gastroscopy because hepatoportal enterostomy site-examination was attempted. During the procedure a fatal venous air embolism occurred which was confirmed at autopsy. The authors proposed that the embolism had been caused by air entering the large hepatic veins just below the enterostomy site [6].

In addition to its optical systems for forward or side view, a gastroscope is equipped with a device for infusing rinsing liquid to clean the mucosa. Aspiration of fluids or the insufflation of air to dilate hollow organs is also possible. Our tests with a commercial gastroscope showed that overpressures of up to 45 kPa can be generated within only a few seconds if there is no possibility of air drainage. We consider this pressure is easily sufficient to produce an air embolism if a suitable connection with a vascular structure is also present. This is the case whenever a vessel is prevented from collapsing because of natural anatomical conditions in specific regions of the body or because of pathological changes of the surrounding tissue [7].

In the case reported here it is most probable that the end of the gastroscope became trapped in the niche. Subsequent attempts to dilate the organ and restore visibility by air insufflation caused air to enter the eroded vessel and ultimately led to air embolism. The vessel was not able to collapse because the gastric wall had become fibrotic after repeated ulceration in this part of the stomach. The gastroscope pumped pressurized air into the exposed vessel. Subsequently the air gained access to the venous bed and to the right heart mainly via portacaval anastomoses but also via the liver although probably to a lesser extent. The possibility of air entering via the peripheral venous access was excluded anamnestically and there was no central vascular access [2].

As air is infused at a rate of about 30 ml per second when the gastroscope is operated at full capacity, a critical condition was bound to occur very quickly. From the literature the volume of air needed to cause fatal air embolism ranges from 70–130 ml if the rate of infusion is

high. The velocity of air insufflation thus plays a crucial role [7–9].

Air embolism is a rare complication in medical practice and is therefore often overlooked. In many cases a fatal outcome cannot be prevented even if the diagnosis is made without delay.

The quantity of insufflated air and the rate of infusion are decisive for the outcome [8, 10]. Prophylactic measures to avoid air embolism in diagnostic and surgical procedures are therefore highly important. In gastroscopy the complication of air embolism, even though extremely rare, should receive proper attention. The complications outlined in our study and case report could probably be avoided if only gas (CO_2) and not air was insufflated to dilate the organ for visibility improvement. In arthroscopy, fluid or gas (CO_2) has been used in preference to air to avoid this very problem [11]. The hazards of endoscopy can be further minimized by considerably reducing the maximum possible pressure.

Not only the clinician but also the pathologist should be aware of this peculiar complication in context with routinely performed gastric examinations.

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