Suspected Arterial Gas Embolism After Glossopharyngeal Insufflation in a Breath-Hold Diver

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Introduction: Many competitive breath-hold divers employ the technique of glossopharyngeal insufflation in order to increase their lung gas volume for a dive. After a maximal inspiration, using the oral and pharyngeal muscles repeatedly, air in the mouth is compressed and forced into the lungs. Such overexpansion of the lungs is associated with a high transpulmonary pressure, which could possibly cause pulmonary barotrauma. ***Case Report:*** We report a case of transient neurological signs and symptoms occurring within 1 min after glossopharyngeal insufflation in a breath-hold diver. He complained of paresthesia of the right shoulder and a neurological exam revealed decreased sense of touch on the right side of the neck as compared to the left side. Motor function was normal. The course of events in this case is suggestive of arterial gas embolism. ***Discussion:*** Although the diver recovered completely within a few minutes, the perspective of a more serious insult raises concerns in using the glossopharyngeal insufflation technique. In addition to a neurological insult, damage to other organs of the body has to be considered. Both acute and long-term negative health effects are conceivable.

Keywords: glossopharyngeal insufflation, lung packing, pulmonary barotrauma, volutrauma, apnea, competitive breath-hold diving.

BREATH-HOLD DIVING as a competitive sport has gained increasing interest in recent years, with records showing an unprecedented development. Currently, the world record for "static apnea" (apnea during rest at the surface of a pool) is 11 min 35 s, for "dynamic with fins" (horizontal underwater swim) it is 250 m (~820 ft), and for "no limits" (maximal depth with the help of ballast weight and equipment-assisted ascent) it is 214 m. In order to increase the time and depth of a dive, divers use special techniques or maneuvers. One such technique used to increase the gas volume of the lungs during the dive is called "glossopharyngeal insufflation" or "lung packing." After a maximum inspiration, a mouthful of air is taken with the glottis closed. Thereafter the air in the mouth is compressed using the oral and pharyngeal muscles, the glottis opened and the air forced into the lungs (7,11). This maneuver is performed repeatedly. With glossopharyngeal insufflation, the diver can increase the lung gas volume for the dive by up to 4 L above the normal total lung capacity (9). Due to the fact that the lung has a low compliance at high lung volumes, glossopharyngeal insufflation is associated with a high transpulmonary pressure. Transpulmonary pressures as high as 80 cmH_2O have been reported (9). Such pressures could possibly lead to pulmonary barotraumas (4,11,15) and arterial gas embolism is one conceivable consequence. Remarkably, there are few reports about pulmonary complications associated with glossopharyngeal insufflation, even though competitive breath-hold divers frequently perform this technique (15). Jacobsen et al. (4) reported an asymptomatic pneumomediastinum in one of their subjects after performing glossopharyngeal insufflation. Lindholm et al. (6) presented accounts from three elite breath-hold divers who had experienced neurological symptoms suggestive of arterial gas embolism after glossopharyngeal insufflation. Here we report the case of one breath-hold diver with transient neurological signs and symptoms occurring within 1 min after glossopharyngeal insufflation. The authors directly witnessed the incidence. Informed consent was obtained for publication of the diver's details in this report.

CASE REPORT

The diver in this case participated as an experimental subject at our laboratory in a breath-holding experiment not related to the presented incident. He was an 18-yr-old, healthy nonsmoker (height 177 cm and weight 65 kg) and had been breath-hold diving competitively for 1 yr. He was training for breath-hold diving 5-6 h a week and performed an additional 5-6 h per wk of other forms of physical exercise (swimming, running, and gym training). He routinely practiced glossopharyngeal insufflation in association with breath-hold dives. At the beginning of the experiment the subject performed three vital capacity measurements in the standing position and three measurements in the supine position, all with-

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out glossopharyngeal insufflation. The protocol consisted of 20 apneas of submaximal duration with an inhaled lung volume corresponding to 85% of vital capacity in the supine position, i.e., glossopharyngeal insufflation was not part of the experimental protocol. During apneas, all variables were recorded using noninvasive equipment. The experimental protocol lasted for about 3 h.

After completion of the planned experiment, the diver used, by his own request, our spirometer in order to measure maximal exhaled volume from the lungs after glossopharyngeal insufflation. This is a frequent request from competitive breath-hold divers volunteering for various types of experiments at our laboratory. In the standing position he performed a maximal inhalation and glossopharyngeal insufflation followed by a maximal exhalation through the spirometer mouthpiece. The exhaled volume was 8.66 L, as compared to the vital capacity of 6.79 L measured at the beginning of the experimental session. About 30-60 s after the measurement the diver appeared uncomfortable and expressed feelings of distress. He complained of paresthesia of his right shoulder. A neurological exam revealed decreased sense of touch on the right side of the neck as compared to the left side. Motor function was normal. After a further 2-3 min, the paresthesia had disappeared, but the decreased sense of touch on the right side of the neck was still present. The latter was normal 1 min later. We supervised the diver for 60 min without any new signs or symptoms. The diver claimed that he had never experienced any similar symptoms from the technique previously. Nevertheless, we informed him about our concerns regarding any future use of glossopharyngeal insufflation.

During the most recent contact with the diver, 18 mo after the incident, he disclosed that he has continued to practice glossopharyngeal insufflation. However, on account of his own concerns caused by the incident, he has refrained from maximizing the amount of volume added to the lungs by the technique. He has not experienced any new incidents involving comparable symptoms brought about by glossopharyngeal insufflation.

DISCUSSION

This report describes neurological signs and symptoms occurring shortly after overexpansion of the lungs by glossopharyngeal insufflation in a breath-hold diver, suggestive of arterial gas embolism. The present signs and symptoms are in agreement with an effect on the somatosensory pathways of the third and possibly fourth cervical nerves. Considering the fact that it is known that overexpansion of the lungs can cause arterial gas embolism, the possibility that glossopharyngeal insufflation could lead to arterial gas embolism is not surprising; e.g., arterial gas embolism is a dreaded complication of overexpansion of the lungs or parts of the lungs during rapid ascent from diving with compressed breathing gas (16). Also in aviation medicine, arterial gas embolism from overexpansion of the lungs during a sudden fall in ambient pressure has been discussed (13,14). At 1 atm, arterial gas embolism has been associated with mechanical ventilation in cases where relative high ventilatory pressures and volumes had to be used. Most reports deals with treatment in neonates, but adults are also at risk (5). Regardless of its origin, depending on the size and localization of the arterial gas embolism, neurological signs and symptoms can vary from minor short lasting, to more serious, to death. Thus, even though the breath-hold divers in the present case and in the cases reported by Lindholm et al. (6) recovered completely, the perspective of a serious insult is alarming.

Besides the risk of a neurological insult, other organs of the body, for instance the heart, might also be at risk of a serious insult in association with an arterial gas embolism. Furthermore, overexpansion of a lung with decreased strength of the visceral pleura, such as pleural blebs, might bring about a pneumothorax. Pleural blebs are not uncommon (6%) among young healthy adults (1). In addition, the possibility of long-term damage to the lungs by glossopharyngeal insufflation is of concern. Possible mechanisms may be related to the pathology involved in ventilator-induced lung injury. Overexpansion of the lungs during mechanical ventilation has been blamed for contributing to persistent lung function abnormalities after neonatal respiratory distress syndrome and acute respiratory distress syndrome (18). Those abnormalities include bronchopulmonary dysplasia in neonates and a restrictive defect with abnormal transfer factor in adults.

The glossopharyngeal insufflation technique also has circulatory effects. Increases in intrathoracic pressure reduce venous return and cardiac performance (3). It has been reported that glossopharyngeal insufflation causes reductions in cardiac output (10) and biventricular systolic dysfunction (12). With these changes, the arterial blood pressure is markedly reduced during glossopharyngeal insufflation (10,12). The fall in blood pressure may lead to syncope and such an adverse event has recently been reported (2). The hypotension and syncope were associated with cardiac dysrhythmias, including periods of asystole, and increased serum myoglobin concentrations after the incident, possibly indicating myocardial ischemia (2). As a final point, West et al. (17) state that both an increase in capillary pressure and high states of lung inflation are important factors for stress failure of pulmonary capillaries. Thus, the possible association between pulmonary overinflation by glossopharyngeal insufflation and breath-hold diving induced pulmonary edema deserves further study (8).

The present case should bring to attention that there is a possibility that glossopharyngeal insufflation could produce signs and symptoms suggestive of arterial gas embolism. Although commonly used by competitive breath-hold divers, we do not advocate the use of glossopharyngeal insufflation for overexpansion of the lungs. Breath-hold divers practicing glossopharyngeal insufflation and diving medicine physicians should be aware of the various complications associated with this technique.

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