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CASE REPORT

Gas in Joints After Diving: Computed Tomography May Be Useful for Diagnosing Decompression Sickness

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A 26-y-old experienced scotoma scintillans after 59 min of scuba diving at a maximum depth of 26 m. After the patient smoked a cigarette, the scotoma scintillans ceased. However, he then developed a headache, general fatigue, and shoulder and elbow pain. He therefore called an ambulance. Based on the rules of the medical cooperative system for decompression sickness in Izu Peninsula, the fire department called a physician-staffed helicopter. After a physician checked the patient, his complaints remained aside from a low-grade fever. A portable ultrasound revealed bubbles in his inferior vena cava. Because of the risk of his being infected with COVID-19, he was transported to our hospital not by air evacuation but via ground ambulance staff while receiving a drip infusion of fluid and oxygen. After arriving at the hospital, his symptoms had almost subsided. Whole-body computed tomography revealed gas around the bladder, left hip, right knee, bilateral shoulder, joints, and right intramedullary humerus. The patient received high-concentration oxygen, infusion therapy, and observational admission. On the second day of admission, his symptoms had completely disappeared, and he was discharged. To our knowledge, this is the first report that computed tomography might be useful for detecting gas in multiple joints, suggesting the onset of decompression sickness after diving. This might be the first report of gas in an intramedullary space after diving as a potential cause of dysbaric osteonecrosis.

Keywords: helicopter, normobaric oxygen, imaging

Introduction

Decompression sickness (DCS) is caused by intravascular or extravascular bubbles that form as the result of a reduction in environmental pressure (decompression).[1] Manifestations are most commonly 1 or more of the following: joint pain, hypesthesia, generalized fatigue, or rash.[2] First-aid treatment is administration of 100% oxygen, definitive treatment is recompression to an increased pressure, and adjunctive treatment including fluid administration is also recommended.[1]

In the human body, the cavitation effect has been recognized in radiologic studies. This is called the vacuum phenomenon (VP).[3] The mechanism responsible for the formation of the VP is as follows: If an enclosed tissue space is allowed to expand in a rebound phenomenon after an external impact, the volume within the enclosed space will increase. In the setting of such an expanding volume, the pressure within the space will decrease. The solubility of the gas in the enclosed space will decrease as the pressure of the space decreases. Decreased solubility allows gas to leave a solution. Clinically, the pathologies associated with the VP have been reported to mainly include normal joint motion, degeneration of the intervertebral discs or joints, and trauma. The VP may be accelerated after diving and during the decompression phase. Accordingly, DCS after diving exercise may be induced by the VP, particularly in cases with joint pain.[4] We herein present a case of gas in the joints after diving that was detected by computed tomography (CT), which may be useful for diagnosing DCS.

Case Presentation

A 26-y-old male experienced scotoma scintillans after 59 min of open-circuit compressed-air scuba diving at a

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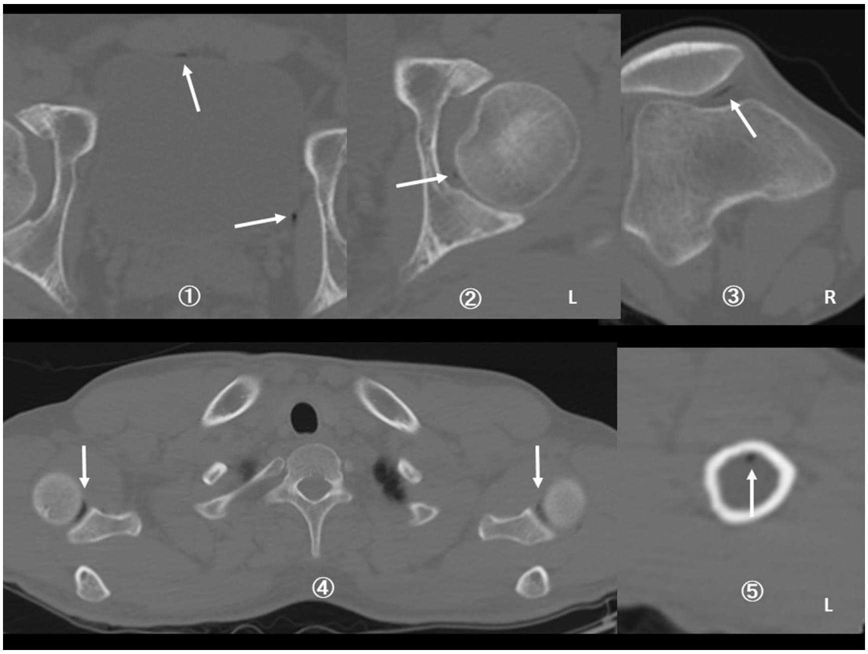

Figure 1. Whole-body computed tomography (CT) findings on arrival. CT shows air density around the bladder (1), left hip (2), right knee (3), bilateral shoulder (4) joints, and right intramedullary humerus (5). There were no lung lesions.

maximum depth of 26 m in Osezaki on the Izu Penisula, Shizuoka prefecture. This dive was a planned profile, and appropriate decompression procedures were performed, according to patient testimony. After the patient smoked a cigarette, the scotoma scintillans ceased. However, he then developed a headache, general fatigue, and pain in both shoulders and elbows that did not improve spontaneously. Given his extensive scuba diving experience (475 times), he suspected that he had DCS and called an ambulance. He had a history of hay fever and otitis media.

Based on the rules of the medical cooperative system for DCS in Izu Peninsula, the fire department called a physician-staffed helicopter, known as a doctor helicopter (DH) in Japan.[5,6] He was transported to a near rendezvous point by the ambulance. When a physician transported by the DH checked him at 160 min from the onset of symptoms, his symptoms remained. His vital signs were as follows: blood pressure, 120/82 mm Hg; heart rate, 90 beats·min^{-1}; respiratory rate, 20 breaths·min^{-1}; percutaneous oxygen saturation 100% while breathing 10 L·min^{-1} of oxygen; and body temperature, 37.8°C. The DH physician knew at the rendezvous point that the patient had come from Tokyo, where COVID-19 infection was prevalent, and had a low-grade fever. Because a portable ultrasound revealed bubbles in his inferior vena cava, he was diagnosed with DCS or air embolism by barotrauma at the scene, as well as suspected COVID-19 infection. At any other time, he would have been transported to a hospital for recompression treatment using a multiplace hyperbaric chamber with 15-min air evacuation. However, because he was suspected of having COVID-19 infection, he was transported to our hospital not by air evacuation but via ground ambulance staff while receiving a drip infusion of fluid and oxygen. The DH departed the scene without the patient because the position statement from the Japanese Society for Aeromedical Services (April 21, 2020) recommends that the DH not transport patients with verified or suspected COVID-19 infection to avoid infecting DH staff with COVID-19.

At 205 min after the onset of symptoms, he was transported to our hospital. His vital signs showed no significant change, but his symptoms had almost completely subsided. Whole-body CT revealed gas around the bladder, left hip, right knee, bilateral shoulder joints, and right intramedullary humerus (Figure 1). There were no lung lesions. The laboratory findings are shown in Table 1.

Our hospital had a monoplace hyperbaric chamber, but the patient underwent only high-concentration oxygen, infusion therapy, and observational admission to prevent secondary infection. The next day, his symptoms

Table 1. Laboratory analysis findings

Analysis	*Value*	*Normal values*
pH	7.37	7.35–7.45
PCO_2, mm Hg	45.7	35–45
HCO_3^-, mmol·L^{-1}	26.2	22–26
Base excess, mmol·L^{-1}	1.1	±2
Lactate, mmol·L^{-1}	2.6	0.5–1.8
Cell blood count		
White blood cell count	14,500	3600–8900·µL^{-1}
Hemoglobin	14.6	11.1–15.2 g·dL^{-1}
Platelet count	20.0×10^4	15.3–34.6 ×10^4·µL^{-1}
Serum biochemistry		
Total protein, g·dL^{-1}	6.3	6.5–8.5
Albumin, g·dL^{-1}	4.1	4–5.2
Total bilirubin, mg·dL^{-1}	0.8	0.4–1.2
Cholinesterase, IU·L^{-1}	162	178–433
Aspartate aminotransferase, IU·L^{-1}	19	5–37
Alanine aminotransferase, IU·L^{-1}	9	6–43
γ-glutamyl transpeptidase, IU·L^{-1}	10	0–75
Alkaline phosphatase, IU·L^{-1}	189	110–348
Creatine phosphokinase, IU·L^{-1}	149	47–200
Amylase, IU·L^{-1}	69	43–124
Blood urea nitrogen, mg·dL^{-1}	10.4	9–21
Creatinine, mg·dL^{-1}	0.97	0.5–0.8
Glucose, mg·dL^{-1}	96	65–109
C reactive protein, mg·dL^{-1}	<0.02	0
Sodium, mEq·L^{-1}	140	135–145
Potassium, mEq·L^{-1}	3.7	3.5–5
Chloride, mEq·L^{-1}	104	96–107
Coagulation		
Activated partial thromboplastin time, s	32.9	26.9[a]
Prothrombin time, s	11.7	11.7[a]
Fibrinogen, mg·dL^{-1}	176	160–400
Fibrinogen degradation products, µg·mL^{-1}	1.9	0.1–5

[a]Control.

had completely disappeared, and he was discharged, returning to Tokyo by car. In the end, polymerase chain reaction for COVID-19 was negative.

Discussion

Our hospital routinely uses whole-body CT to diagnose trauma for patients with severe trauma, cardiac arrest, or septic shock.[3,7,8] However, we had never previously encountered gas in multiple joints, as was seen in the present case, except for necrotizing soft tissue infection.[7] Because the present case had normal C reactive protein values on arrival, the possibility of necrotizing soft tissue infection could thus be ruled out. In addition, gas in an intramedullary space or gas around the bladder could not be explained by the VP theory. In particular, this might be the first report of gas in an intramedullary space after diving as a potential cause of dysbaric osteonecrosis (avascular bone necrosis).

Furthermore, we reviewed 100 recent consecutive cases of whole-body CT ordered by our department. Only 1 trauma patient showed gas in the right shoulder joint space. Accordingly, we believed that the present case was DCS and did not consider this a machine-specific or calibration flaw (artifact). The CT scan including painful joints after diving may thus be useful for diagnosing DCS. However, no definite methods have yet been established to clearly differentiate between DCS and simple VP concerning gas in the joints. In the present study, the painful elbow joints failed to show gas, whereas the painless hip and knee joints did show gas. This might be due to gas in the painful joints having resolved by the time the imaging was performed. As a result, further clinical investigations are warranted to determine how and when to diagnose the bends.

Conclusions

This might be the first report of gas in an intramedullary space after diving as a potential cause of dysbaric osteonecrosis. CT scan including painful joints after diving may thus be useful for diagnosing DCS.

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