

The Vacuum Phenomenon in the Ankle Joint – Air Bubbles on CT

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Introduction

The presence of gas or air bubbles in a joint was first described by Fick in 1910 when he noticed gas bubbles in hand joints on radiograph (XR) evaluation while under traction.¹⁻³ This XR finding was coined the “vacuum phenomenon” (VP) by Magnusson in 1937.² On CT the shape is classically defined as a crescentic lucency of air bubbles paralleling a joint when found articular.³ The VP relates to Henry’s Law and Boyle’s Law through hydrodynamic cavitation in that gas precipitates out of solution through a negative intra-articular pressure when a joint is distended or collapses that normally goes back into solution when the joint returns to its normal volume and pressure.

Gas bubbles were first thought to be associated with joint traction or trauma, but has since been found in situations of degenerative changes to joints.¹⁻² Other associated gas bubble presenting pathologies include closed/open fracture-dislocation, ligament injury, metastasis, infection, cancer, intravertebral disc herniation, abdominal or thoracic free air, and iatrogenic causes.^{2,4} Related to degenerative disease, its presence is most often cited to the sacroiliac (SI) joints, but also has been found in the joints of the wrist, hand, hip, shoulder, knee, ankle (AKJ), subtalar (STJ), and calcaneocuboid (CCJ).¹⁻⁴ Analysis of the gas in the SI location has found it to be predominantly nitrogen (> 90%) based, with low concentrations of oxygen, carbon dioxide, and other gases.² The purpose of this report was two-fold: to determine the rate of occurrence of foot and/or ankle VP in the literature through a key word search and present a case example of the VP to the AKJ in an end-stage degeneration clinical situation.

Methods

A PubMed® advanced key word search was performed on May 1, 2017, using the term combinations of “air bubble,” “bubble,” “gaseous degeneration,” “vacuum phenomenon,” with “foot” or “ankle.” The search had no restriction parameter fields applied. (see Table) The returned abstracts were reviewed to determine their validity whether relevant to the primary search goal of obtaining articles demonstrating the VP from the ankle joint, distally. A table was then created counting the published instances of the VP in the foot and/or ankle.

ANKLE	FOOT
• “air bubble” / “ankle”	• “air bubble” / “foot”
• “bubble” / “ankle”	• “bubble” / “foot”
• “gaseous degeneration” / “ankle”	• “gaseous degeneration” / “foot”
• “vacuum phenomenon” / “ankle”	• “vacuum phenomenon” / “foot”

Citations available upon request.

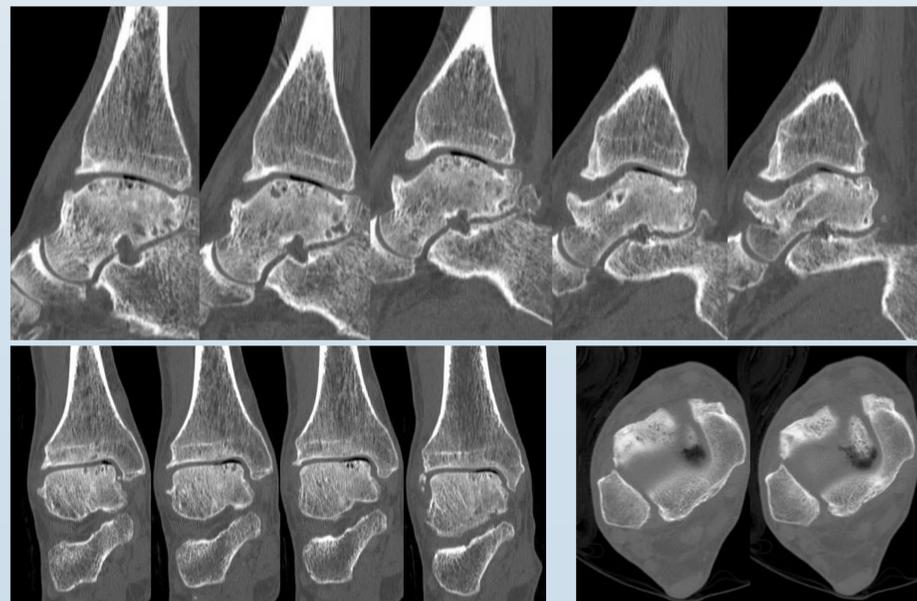
Case Report

A 50 year old male patient presents to a senior authors office due to his primary complaint of left ankle pain described as progressive pain upon ambulation that has increased over the recent years with a reduction in his activity level. Treatments to date included rest and NSAID medication with minimal relief. The patient’s past medical history consists of hemochromatosis with no past surgical or related family history to the ankle condition. 12 point review of systems was negative other than for isolated ankle pain.

Physical exam findings revealed limited dorsiflexion (dfx) at the ankle joint and pain upon end range of motion DFX with a hard stop. His neurovascular status was grossly intact. There were no subjective complaints or objective findings of an infectious process based on the history and physical exam. He had no complaints of any other arthritic or painful joints. No other abnormalities were noted to his problem based exam.

A CT scan of the ankle exhibited degenerative joint disease to the talo-tibial joint along with a large anterior osteophyte of the distal tibia and talar neck at the ankle joint level. The CT scan also exhibited intra-articular gas centrally within the joint. (Figs. below) Facility radiologists stated the gas was a VP presentation due to nitrous oxide from surrounding synovial tissues.

Image review and treatment options were discussed with the patient. He is still considering his options, managing with conservative therapy modalities, and has not had surgical intervention to date.



Note: (sagittal) Gas in the joint and within the subchondral bone region with associated talar dome arthritic changes; (coronal) Gas centered around, and within the cystic changes to the medial talar dome; (axial) Gas within the lower-lying cartilage defect space.

Results

From the PubMed® literature search, 33 articles resulted in total.

After reviewing titles, abstracts, and database tags, removing irrelevant and duplicate entries, only two articles were relevant to this literature review of identifying examples of the VP in the foot and/or ankle. (Table 2) This included a retrospective institutional review of CT imaging over two years evaluating the presence of gas bubbles in the lower extremity joints (i.e., AKJ, STJ, CCJ) and a case example of the VP in the STJ and CCJ after a trauma.^{1,5} A third study found discussed a drop foot secondary to epidural gas formation and nerve root compression was not counted due to the distance location of the gas bubbles from the foot.⁶

Discussion

- In situations of arthritis, a thickened or fibrotic/scarred joint capsule does not allow gas to easily dissolve out. Furthermore, excess joint space due cartilage loss and subchondral cysts allows the gas to remain out of solution to fill that “extra” space.¹ Both factors can alter the normal dynamics of the VP.
- The presence of the VP may be seen as something no more than an academic finding when present on a joint CT scan. However, it is important to correlate the finding to the presenting pathology so to not over/under diagnose the true pathology at hand.^{2,3} Differentials to rule out include infection (septic joint), open vs closed fracture-dislocation, or penetrating joint trauma.^{1,5,7}
 - Specific to the lower extremity two studies were found:
 - Lee et al. (1994) - retrospective review of CT scans over a two year period to determine the incidence of gas within the STJ ± AKJ finding 12 cases (n = 495, 2.4%): 11 = arthritis (post-traumatic, 10; non-traumatic, 1); 10 = STJ; 0 = infection; all with XR visible DJD and CT visible DJD and VP.¹
 - Ahmad et al. (2007) – single VP case of an acute, closed STJ and CCJ fracture-dislocation.⁵
- The authors surmised the VP finding in the lower extremity may not be seen in high percentages due to two more reasons. These are based on the physics of the VP and some speculation:²
 - VP is most sensitive on CT imaging. In the acute injury settings such as an ankle sprain, gas bubbles may be routinely seen within 4 hours of injury while occasionally seen after 48 hours on CT scan while another study found bubble to disappear within 10 minutes. Therefore VP is rarely visible on advanced imaging due to quickly dissolving back into solution.^{3,8}
 - In situations of chronic degenerative disease, over time the gas within the joint achieves a new solubility equilibrium and will dissolve back into solution and not be visible. The time to reach equilibrium was not found in any report.