

Vacuum phenomenon in equine carpal, metacarpophalangeal and metatarsophalangeal joints

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ABSTRACT

In order to establish the incidence of vacuum phenomenon in horses' carpal, metacarpophalangeal and metatarsophalangeal joints, stress-flexed radiographs were made of normal joints, joints with known pathology and in anaesthetised horses with joints under traction. Focal intra-articular radiolucencies were identified in normal stress-flexed carpal, metacarpophalangeal and metatarsophalangeal joints. These radiolucencies can be confused with those associated with pathological conditions.

Key words: equine, joint, radiograph, vacuum phenomenon.

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INTRODUCTION

The vacuum phenomenon is recognised in joints in which stress distracts the opposing articular surfaces¹³. It has been postulated that increasing the joint space creates a negative pressure that attracts gas from surrounding extracellular spaces⁹. This gas then accumulates in the joint², filling the void created in the synovial fluid¹³.

Radiographically, gas has commonly been noted between human articular facets and intervertebral disc spaces^{4,8,12,13} associated with degenerative disc disease. Other sites in humans where the vacuum phenomenon has been seen include the shoulder⁹, knee³, hip^{9,17}, metacarpophalangeal¹⁹, sternoclavicular and sternocostal joints¹⁴. The most widely recognised example of this phenomenon is secondary to the traction-induced vacuum seen in hyper-extended shoulders and hips in paediatric radiographs^{9,10}.

In dogs the vacuum phenomenon has been described in the scapulo-humeral joint associated with osteochondrosis¹⁶, in intervertebral discs associated with other radiographic features of degeneration⁵, and in the sternum¹⁸ and coxofemoral joints⁷. In horses this phenomenon has been described in the metatarsophalangeal joint of 2 horses, 1 with a subluxated joint, and 1 with a normal joint¹⁵.

During routine flexed radiographic studies of horses at the Veterinary Academic Hospital, University of Pretoria, focal radiolucencies have been seen occasionally in carpal and metatarsophalangeal joints. These were interpreted as representing vacuum phenomena. This study determines the radiographic incidence of the vacuum phenomenon in stress-flexed normal and pathological carpal, metacarpophalangeal and metatarsophalangeal joints.

MATERIALS AND METHODS

The incidence of vacuum phenomenon was established in horses with clinically normal joints, in joints with known pathology and in anaesthetised horses with joints under traction.

Part 1 of the study was to assess the incidence of the vacuum phenomenon in clinically normal horses. Survey radiographs of carpal, metacarpophalangeal and metatarsophalangeal joints were made. These joints were selected for the ease with which they can be radiographed and because the vacuum phenomenon has been described previously in the metatarsophalangeal joint of a horse¹⁵. Joints were included in the study only if no major radiographic abnormalities were present in standard lateromedial, dorsopalmar (plantar), dorsolateral-palmaro (plantaro) medial oblique, dorsomedial-palmaro (plantaro) lateral oblique and flexed lateromedial views of the relative joints of both left and right limbs. Ten pairs of carpal, metacarpophalangeal and metatarso-

phalangeal joints in 16 horses were included in the study. Four horses were geldings and 12 were mares. All horses were Thoroughbreds aged 3–15 years (mean 9.9 years) showing no clinical signs of lameness in the joints radiographed and weighing 446–618 kg (mean 499 kg). For the trial, lateromedial radiographic views were made of each joint in the following order: weight-bearing; passively flexed 45°, maximally flexed (stress flexed), passively flexed 45° and a weight-bearing view were made followed by a dorsopalmar view in the weight-bearing position. If any gas was noted in the joints on these radiographs, an additional passively flexed 45° view was made approximately 5 min after the maximally flexed view.

Part 2 of the study evaluated 20 anaesthetised horses suspended from an overhead crane by means of leather hobbles attached to their phalanges. Seventeen Thoroughbreds, 2 Hanoverians, 1 Arab and 1 Friesian with weights ranging from 388–550 kg (average 455 kg) and ages from 2–14 years (average 5 years) were used. Radiographs were made in the induction room before the horses were moved into the theatre for surgical procedures not related to the radiographed limbs. Lateromedial views were made of either the left or right carpal, metacarpophalangeal and metatarsophalangeal joints. The 60 joints were chosen at random and were not evaluated clinically or radiographically before the procedure. All radiographs were made within 15 min of suspending the horse.

Part 3 of the study evaluated clinically and radiographically pathological joints. Radiographic pathology was diagnosed from the abovementioned standard views of the joint. This was followed by an additional lateromedial maximally flexed radiograph of the same joint. Twenty-four carpi from 20 horses and 15 metacarpophalangeal and 9 metatarsophalangeal joints from a different group of 20 horses were evaluated. Included in this study were 2 metatarsophalangeal joints and 1 carpus without radiologically-detectable pathology but with clinical lameness

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emanating from them. This was verified by intra-articular anaesthesia performed not less than 24 hours before making the maximally flexed radiographs.

All radiographs were made using non-grid exposures, Trimax T6 screens (3M, Elandsfontein, South Africa) and a source-to-image distance of 100 cm. Exposure factors of 90 kV 1 mAs were used for the metacarpo- and metatarsophalangeal joints, and 93 kV 1 mAs for the carpal joints to provide long-scale contrast for optimal soft-tissue and gas visibility. Standard automated radiographic development techniques were employed.

Radiographs were evaluated by all authors independently. Where opinions differed, consensus was obtained. Size, anatomical location and persistence of the gas was evaluated. When doubt existed whether a radiolucency was caused by superimposition and summation of bones or caused by the vacuum phenomenon, it was interpreted as being caused by summation.

RESULTS

Gas was detected in 1 carpus, 1 metacarpophalangeal joint and 3 metatarsophalangeal joints in Part 1 of the study.

No gas was detected in any of the joints in Part 2 of the study. Carpal joints did not appear to be widened by the weight of the suspended horse whereas metacarpo-(metatarso)phalangeal joints widened up to 2 mm. It was difficult to obtain ideally positioned lateromedial views owing to the elevated position of the joints. Minor degenerative changes were present in some joints.

In Part 3 of the study, no gas was detected in any of the carpi radiographed. Gas was present in 1 metacarpophalangeal joint that showed no radiological pathology but had lameness localised to the joint. When joints that initially showed vacuum phenomena (Parts 1 and 3) were radiographed in a non-stressed flexed position 5 min later, no gas was detected. No additional views were made to see if gas was persistent, as no gas was present in Part 1 of the study when passively-flexed views were made 5 min after the maximally-flexed views were made.

In the carpus, gas accumulated in the intercarpal joint distal to the intermediate and radial carpal bones. Small peri-articular osteophytes were present on the dorso-distal radial and intermediate carpal bones (Fig. 1). In the metacarpophalangeal joint a rectangular radiolucency was present dorsal to the articular surface of the sesamoids (Fig. 2). In the metatarsophalangeal joints, gas typically localised distal to the plantar articular

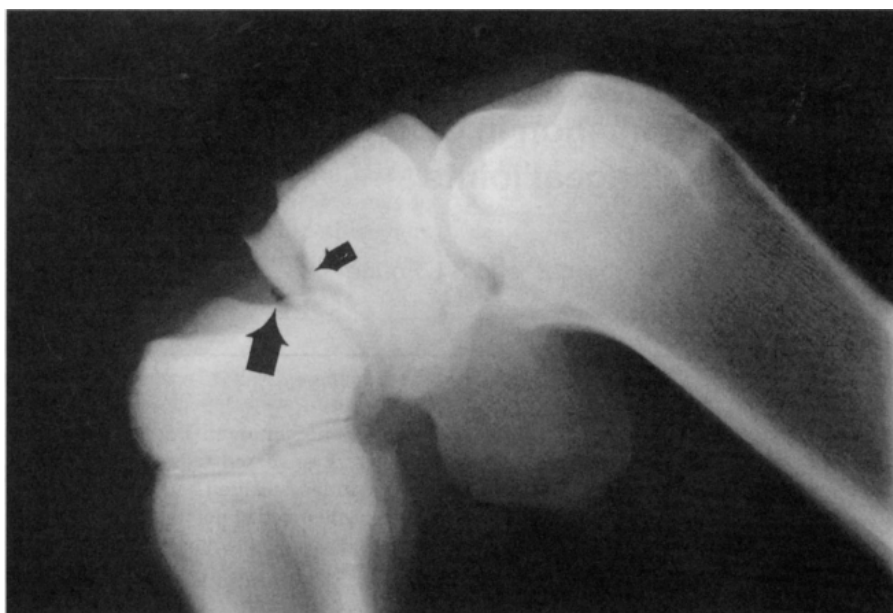


Fig. 1: Radiolucencies (vacuum phenomenon) distal to intermediate (small arrow) and radial (large arrow) carpal bone.

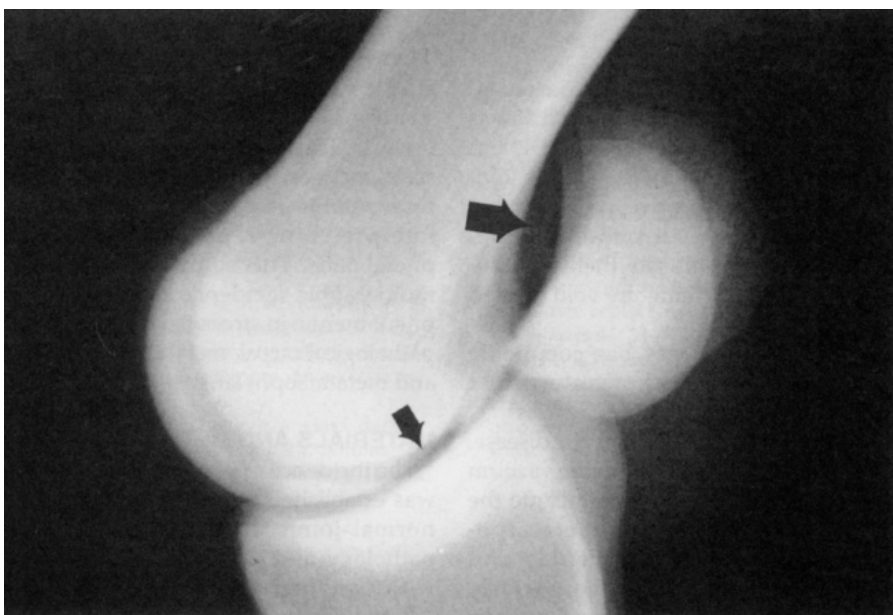


Fig. 2: Metacarpophalangeal joint. A rectangular radiolucency with multiple small oval/circular superimposed radiolucencies is present dorsal to the articular surface of the proximal sesamoid bones (large arrow). Note the apparent radiolucency (small arrow) caused by superimposition of bones.

surface of the condyles of the 3rd metatarsus (Fig. 3).

DISCUSSION

Analysis of gas aspirated from human lumbar discs with vacuum phenomenon consists of 92 % nitrogen combined with oxygen, carbon dioxide and traces of other gases². The vacuum phenomenon has been explained by anatomical and physiological factors^{2,12,13,15,16}. When opposing articular surfaces are distracted, a space is created that must be filled. If there is insufficient fluid to fill the

expanded space, gas in the surrounding extracellular fluid escapes from solution and occupies the volume created by distraction, thereby producing the vacuum phenomenon, resulting in a physiological pneumoarthrogram. When the joint returns to opposition the space is obliterated and the gas is resorbed. If the joint is kept distracted, the gas disappears after a few minutes owing to the accumulation of fluid in the joint³. This may indicate that gas in solution diffuses more readily than fluid, which then later fills the available space. In the presence of synovial

Table 1: Joints demonstrating vacuum phenomenon.

Joint	Anatomical position	Size	Description
Normal joints			
Right carpus (Fig. 1)	Distal to intermediate and radial carpal bones	10 × 2 mm 3 × 6 mm	Linear Triangular in shape with indistinct distal margin
Left metacarpophalangeal (Fig. 2)	Dorsal to articular surface of sesamoids	3 × 6 mm	Rectangular radiolucency with multiple 1 mm diameter oval to circular superimposed radiolucencies
Left metatarsophalangeal	Plantar distal to condyle of 3rd metacarpus	5 × 3 mm	Triangular in shape
Right metatarsophalangeal	Plantar distal to condyle of 3rd metatarsus	8 × 4 mm	Crescent-shaped with indistinct distal margin
Left metatarsophalangeal	Plantar distal to condyle of 3rd metatarsus	8 × 3 mm	Crescent-shaped with two 1 mm diameter superimposed radiolucencies
Anaesthetised horses under traction			
None	—	—	—
Pathological joints			
Left metatarsophalangeal (Fig. 3)	Plantar distal to condyle of 3rd metatarsus	15 × 4 mm	Oval

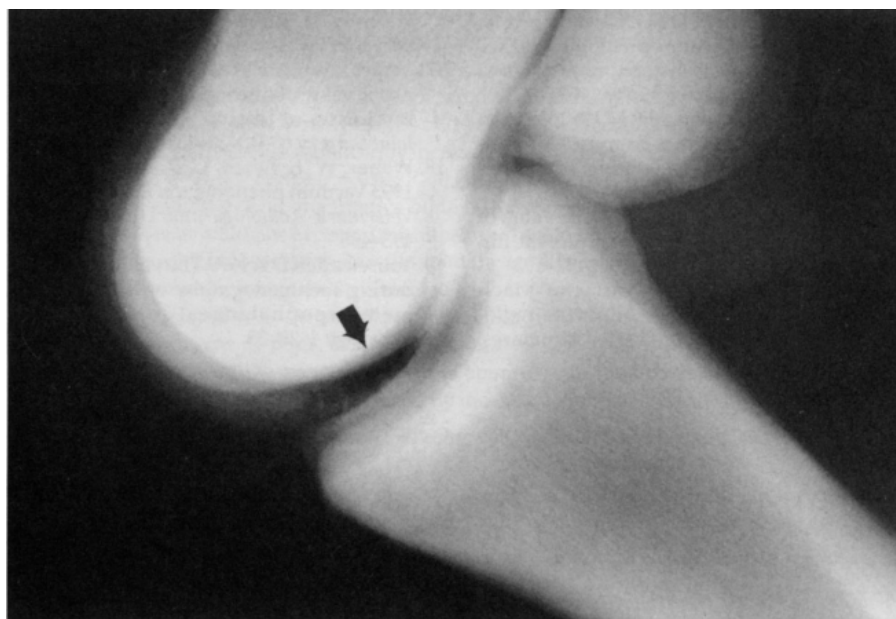


Fig. 3: Metatarsophalangeal joint demonstrating the vacuum phenomenon typically positioned distal to plantar surface of condyle of 3rd metatarsus (arrow).

effusion, a vacuum phenomenon will usually not occur with distraction of the articular surfaces^{13,15-17,19}. This, however, is not always the case, as a vacuum phenomenon has been demonstrated in a human knee with an acutely injured anterior cruciate ligament accompanied by the presence of effusion and haemarthrosis³. In joints with irregular articular surfaces the vacuum phenomenon has been shown to occur spontaneously in fissures and clefts of vertebral articulations^{5,8} without traction. Movement evidently increases the space in these fissures, thereby attracting gas from the surrounding tissues^{12,13}.

In humans the incidence of the spinal vacuum phenomenon increases with age⁸. In this trial, owing to insufficient numbers, the effect of age and sex on the incidence of the vacuum phenomenon could not be established. Traction-

induced vacuum seen in hyper-extended shoulders and hips in paediatric radiographs is dependent on muscular development, muscle tone and laxity of the joint capsule and ligaments⁹. It is limited in advanced osteoarthritis by capsular thickening and muscular spasm¹⁷.

In humans, distraction with a resultant pneumoarthrogram is used as a means of detecting abnormalities of the articular cartilage. Absence of the vacuum phenomenon in distracted hips indicates the presence of synovial effusion^{9,10}. Traction, rotation or abduction can create the phenomenon as apposing articular surfaces are distracted. Using an overhead crane in anaesthetised horses it was not possible to produce the vacuum phenomenon in joints under investigation. This difference may be due, in part, to our inability to cause sufficient distraction in equine joints and the time lapse

between initiation of traction and making the radiograph.

In humans the vacuum phenomenon is a reliable indicator of intervertebral osteochondrosis, intervertebral ischaemic necrosis of bone and, rarely, spinal infection¹. In the scapulo-humeral joint of dogs, the phenomenon is found with osteochondrosis¹⁶ associated with a cartilage flap and a lack of joint effusion. In this trial, the presence of radiographic pathology in carpal, metacarpophalangeal, and metatarsophalangeal joints, was not associated with an increased presence of the vacuum phenomenon in stress-flexed radiographs. Radiographic pathology present in the joints included osteochondral fragmentation and degenerative joint disease. The lack of vacuum phenomenon may be due to the presence of joint effusion¹⁷ preventing space formation, or a compliant joint capsule¹⁵ or the fact that stress flexion was resisted by most of the horses due to pain. Pain and resistance from the horse would result in difficulty in obtaining sufficiently flexed views and also delayed the time when the exposure was made, allowing time for any gas to disappear. Capsular thickening¹⁵ due to osteoarthritis would also limit the degree of joint distraction.

In humans the absence of the vacuum phenomenon when manual traction is placed on the metacarpophalangeal joints is a reliable indicator of joint effusion⁹. This does not appear to be the case in horses.

Stress flexion of a horse's metatarsophalangeal¹⁵, metacarpophalangeal or carpal joints may induce the vacuum phenomenon which could lead to an incorrect interpretation and result in misdiagnosis of osteochondral defects or fractures. Radiolucencies attributable to gas may also be seen in radiographs of joints after arthrocentesis, surgery, sepsis, intra-synovial anaesthesia⁶ or trauma.

Summation, *i.e.* radiological opacities created by the partial superimposition of more than one bony structure, may also result in relative radiolucencies, (negative Mach line) adjacent to it, mimicking a vacuum phenomenon¹¹ (Fig. 2). These apparent radiolucencies can be distinguished from the vacuum phenomenon by being less radiolucent and their borders continuing beyond the edges of adjacent bones. The presence of radiolucencies in radiographs of equine joints should always be interpreted with care and due consideration to the clinical findings.

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