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EXTRAVERTEBRAL GAS AND FLUID EFFUSIONS ASSOCIATED WITH VERTEBRAL COLLAPSE CONTAINING A VACUUM CLEFT POSSIBLY RESULT FROM A PUMPING PHENOMENON: A NEW EVIDENCE OF THE DYNAMIC HYDRO-PNEUMATICAL NATURE OF THE SO-CALLED VACUUM PHENOMENON

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We report two very unusual observations in which gas and fluid effusions were transiently and unexpectedly found in the extravertebral spaces of patients presenting with painful necrotic vertebral collapse containing a vacuum cleft. We hypothesize that gas and/or fluid which progressively may replace vacuum in vertebral compression fractures could be secondarily pumped through extravertebral and retroperitoneal spaces.

Although being rare, these observations may represent a potential missing link in the imaging snapshots of the cyclic and dynamic vacuum phenomenon.

Key-words: Spine, diseases – Spine, CT.

Although true physical-chemical experimental proofs are lacking in the literature, numerous clinical reports have shown that many radiological manifestations of the so-called "vacuum phenomenon" (VP) only represent snapshots of a complex dynamic continuum extending from true vacuum to gas and/or fluid and vice versa (1).

We report two very unusual observations in which gas and fluid effusions were transiently and unexpectedly found in the extravertebral spaces of patients presenting with painful necrotic vertebral collapse containing a vacuum cleft.

We hypothesize that gas and/or fluid which progressively may replace vacuum in vertebral compression fractures could be secondarily pumped through extravertebral and retroperitoneal spaces.

Although being rare these observations may represent a missing link in the imaging snapshots of the cyclic and dynamic VP.

Cases reports

Case 1

An 81-year-old female was admitted in the geriatric department for impairment of general state and severe lumbar pain relating to a recent fall. Plain films of the lumbar spine (not illustrated) showed a classical ischemic osteoporotic collapse of the vertebra L1.

Laboratory results showed a moderate inflammatory syndrome with a CRP level at 53 mg/l.

Abdominal CT was performed to rule out the hypothesis of any occult inflammatory and/or tumoral pathology.

Attention was unexpectedly retained by the presence of unusual extensive bilateral retroperitoneal effusions (Fig. 1) extending from the paravertebral to the retrorenal spaces and along the psoas muscles. These effusions were also extending under both posterior hemi diaphragms and within the retrocrural spaces of the diaphragm. The epicentre of these unusual effusions was constituted by the osteoporotic collapse of the L1 vertebra in which a vacuum cleft was clearly visible.

A single gas bubble was also found within the left paravertebral root of the left psoas muscle (Fig. 1).

New plain films of the lumbar spine were performed in upright (Fig. 2) and supine position (Fig. 2). Moreover lateral plain films (Fig. 2) were also obtained during stress hyperextension on a log in order to appreciate the fracture reducibility. The painful instable vertebral fracture was finally treated by kyphoplasty (Fig. 2).

The symptoms resolved in two days. Postoperative abdominal CT (Fig. 1) showed a complete regression of the retroperitoneal effusions.

Case 2

A 64-year old male was admitted at the emergency room with complaints of acute lumbar mechanical pain after a fall in his bathroom. Supine X-rays of the thoracolumbar spine were performed at admission. They were first considered being normal and the patient was discharged (not illustrated).

Three days later, the patient was readmitted for confusion which was attributed to abuse of analgesics. Severe diffuse lumbar pain was still present and an inflammatory syndrome was associated.

Abdominal CT (Fig. 3) reveals the presence of an intravertebral vacuum cleft within the vertebra T12 suggesting an occult but typical ischemic vertebral collapse. Gas bubbles and edematous effusions were also extensively found outside the vertebra in the retrocrural diaphragmatic spaces.

On sagittal MPR views the discordance between massive intravertebral VP and a normal height of the vertebra suggested the probably spontaneous reduction of the vertebral fracture in the supine position (Fig. 3).

New plain films (Fig. 4) of the lumbar spine were then carefully performed in the upright position unmasking the real amplitude of the vertebral collapse. This collapse immediately reduced on the oblique views performed in the supine position and this caused the reappearance of an acute extensive vacuum cleft (Fig. 4).

The patient was first treated conservatively with lumbar corset but the prognosis of healing was considered poor because the fractured vertebra was situated in the middle of a

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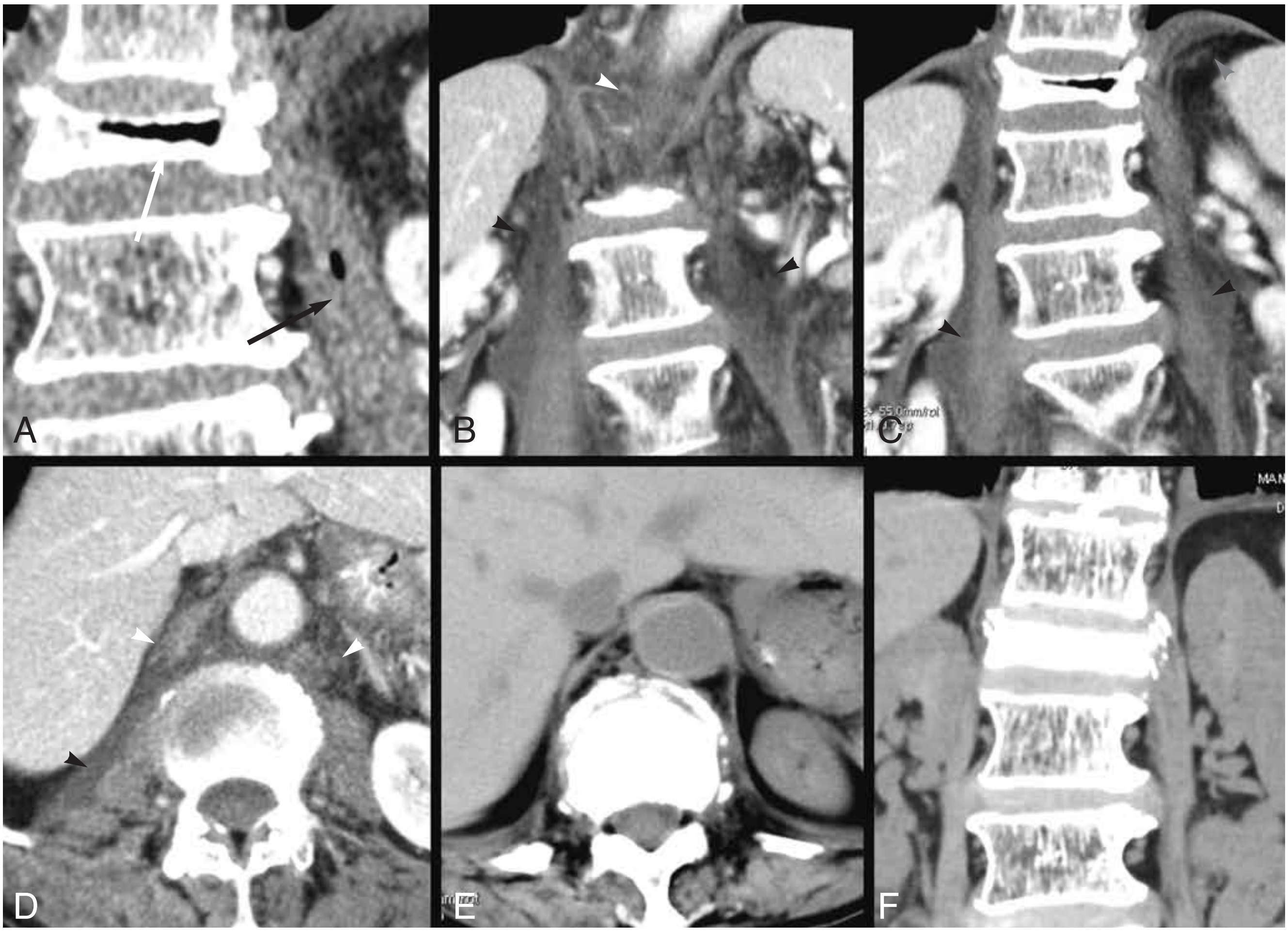

Fig. 1. — Case 1: Coronal MPR CT views (A to C) show a vacuum phenomenon (white arrow) in a severely collapsed L1 vertebra. A gas bubble is also found in the adjacent root of the left psoas muscle (black arrow). More laterally extensive bilateral effusions are found in retroperitoneal paravertebral (black arrowheads), sub diaphragmatic (grey arrowhead) and retrocrural (white arrowheads) spaces. These effusions have completely disappeared two days after kyphoplasty (E, F).

stiff spine segment – due to DISH –. In this condition the fracture site could be subject to inappropriate solicitation in any movement.

A new CT performed one month later showed that paravertebral gas collection had disappeared. The vertebral vacuum had reduced but was still present. The fracture lines had progressed through the posterior arch and epinous process of the vertebra (Fig. 5). It was decided to treat the patient with kyphoplasty and this treatment quickly induced a substantial reduction of the symptoms.

Discussion

Fick was the first to describe the "vacuum phenomenon" in 1910 while he was studying joints under traction (2). In 1937 Magnusson (3) reported the same phenomenon in intervertebral discs and postulated that the creation of spaces, subsequently filled by gas, required a reduction of barometric pressure within a joint and/or a disc up to 1/20 th atmosphere.

In current radiological practice, a vacuum is the physical state of space that is empty of matter. In a synovial joint, a vacuum is produced when the distraction of the articular surface creates a space and there is not enough intraarticular fluid to fill in this space. The negative pressure attracts gas from surrounding tissues into the joint space, creating an intraarticular distended gas pouch. This mechanism is called the vacuum phenomenon. When the distraction of the articular surfaces stops, the produced intraarticular gas may persist.

Gas that forms in a disc was first analysed by Ford in 1977 (4). It contains 90-92% nitrogen combined with oxygen, carbon dioxide and other traces of gases. This composition was confirmed in 1997 by Yoshida et al. who analysed an intraspinal gaseous cyst (5).

VP and gas collections have been described in every segment of the spine including the disc space, Schmorl nodes and vertebral structures, the epidural and intradural spaces, synovial cysts and facet joints (1). They have also been described in numerous peripheral joints or ganglion cysts (6-7), but also in gallstones (8) and unicameral bone cysts (9).

Since the first description by Maldague et al. (6) the presence of an intravertebral gas cleft in vertebral compression fractures – also referred to as "Kümmell disease" (10-13) – is considered indicative of osteonecrosis. It is now commonly regarded as a specific sign for ischemic vertebral

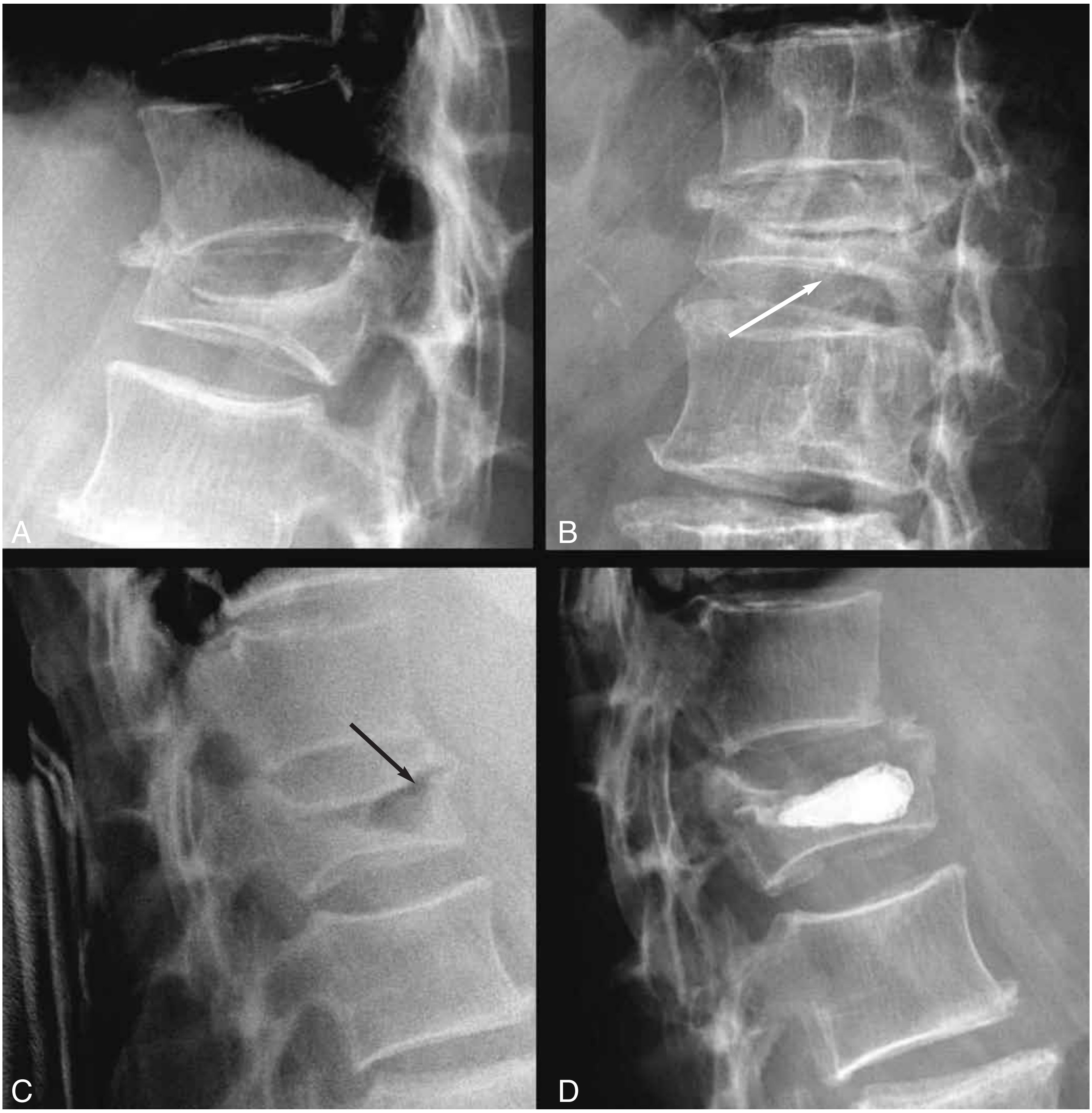

Fig. 2. — Case 1: Upright lateral plain film of the L1 vertebra (A) obtained just after abdominal CT: a major collapse of the vertebra is confirmed. A small vacuum cleft (white arrow) due to acute distraction of the collapse is found on the supine oblique view (B). Stress lateral plain film obtained in hyperextension on a log (C) partially reduced the vertebral collapse and induced an extensive vacuum (black arrow). Upright lateral plain film (D) obtained after kyphoplasty. At the time symptoms have disappeared.

collapse. The most important risk factors for the development of an intravertebral gas cleft are osteoporotic vertebral fractures, steroid medication, trauma, and radiation therapy (11).

Thus a vertebral compression fracture seems to represent the initial event (11). It is followed by a delayed healing due to impaired vascular proliferation and then by osteonecrosis (11, 14). The successive flexions and extensions continuously apply shearing forces to the horizontal fracture line and maintain the absence of fusion of bony fragments. Thus the vacuum cleft represents a peculiar type of vertebral pseudarthrosis.

The abnormal dynamic mobility of the vertebral pseudarthrosis can be demonstrated by a more pronounced gas accumulation (or VP in the acute phase) observed in extension or decompression, a condition classically obtained in the supine position. This can lead to a partial restoration of the vertebral height as illustrated in our reported cases (Fig. 2C, 4, 5C,D).

The VP is not a static phenomenon. On the contrary, various reports (1, 5, 15-18) have suggested

Fig. 3. — Case 2: A. Axial CT views, B, coronal and C, sagittal MPR views of the thoraco-lumbar junction obtained during abdominal CT. Bilateral paravertebral effusions and numerous gas bubbles are found in the paravertebral retrocrural spaces (black arrowheads). Massive intravertebral vacuum is also found in a T12 vertebra of apparently normal height (black arrows). Multilevel ankylosis of the lower thoracic spine is found with typical fatty degeneration of some intervertebral disks (white arrows).

or demonstrated that there was a dynamic physical continuum between true vacuum, gas but also fluid. This continuum seems to depend on the duration and intensity of mechanical stretching – spontaneous or induced by stress – of an anatomical cavity, the variable nature of neighbouring tissues and the variable permeability of the cavity walls. These reported observations are based on various cross-checking clinical observations (1, 5, 15-18).

Malghem et al. (16) have very recently demonstrated the possibility of directly generating intraarticular microbubbles by creating a transient VP during mechanical traction on metacarpophalangeal joints. This study confirms that the real vacuum only represents a transitory state in natural semi-permeable cavities. Gas quickly created by VP replace the transitory vacuum and may persist up to 30 a minutes in suspension in the viscous synovial fluid (16, 19).

Previously Malghem et al. also described the progressive replacement of gas by fluid on plain films and MRI in patients presenting with intravertebral vacuum (15). This replacement was observed after positioning the patients in the supine position for a sufficiently long time (15). The variable duration of this replacement probably depends on several factors: the duration of the decubitus, the intensity of the traction imposed on the spine on stress views or simply by the extension resulting from the supine position and finally the variable permeability of the cleft walls. These observations have been corroborated by others (20). The same phenomenon of replacement of gas by fluid has also been described in cases of intradiscal vacuum during prolonged supine MRI studies (21).

Various observations have also clearly demonstrated that gas accumulating in joints or vertebral disks could also be secondarily progressively forced outside these structures. Gas from apophyseal joints may be forced within cysts of the ligament flava (22-23). Gas from vertebral disks may also be forced within intraspinal gaseous cysts or gas-containing herniations which may produce compressive radicular symptoms. Gas may also simply migrate in the epidural space (5, 24-25). In these gaseous cysts or hernias, gas is generally injected under a certain pressure which is obtained in a stepwise fashion by a "ball-valve effect" or a "valve-pump mechanism" (1, 5). Gas – mixed with synovial fluid – may also be pumped in periarticular synovial cysts (1, 6-7).

In our two cases a similar mechanism could be evoked in which the VP produces an accumulation or gas/or fluid in the vertebral cleft due to the negative pressure induced by distraction of the vertebral cleft during the supine position (suction pumping mechanism). This gas/or fluid collections may be secondarily forced through the extravertebral soft tissues when positive pressure reappears in upright position (force pumping mechanism).

These various but complementary studies unequivocally emphasize the

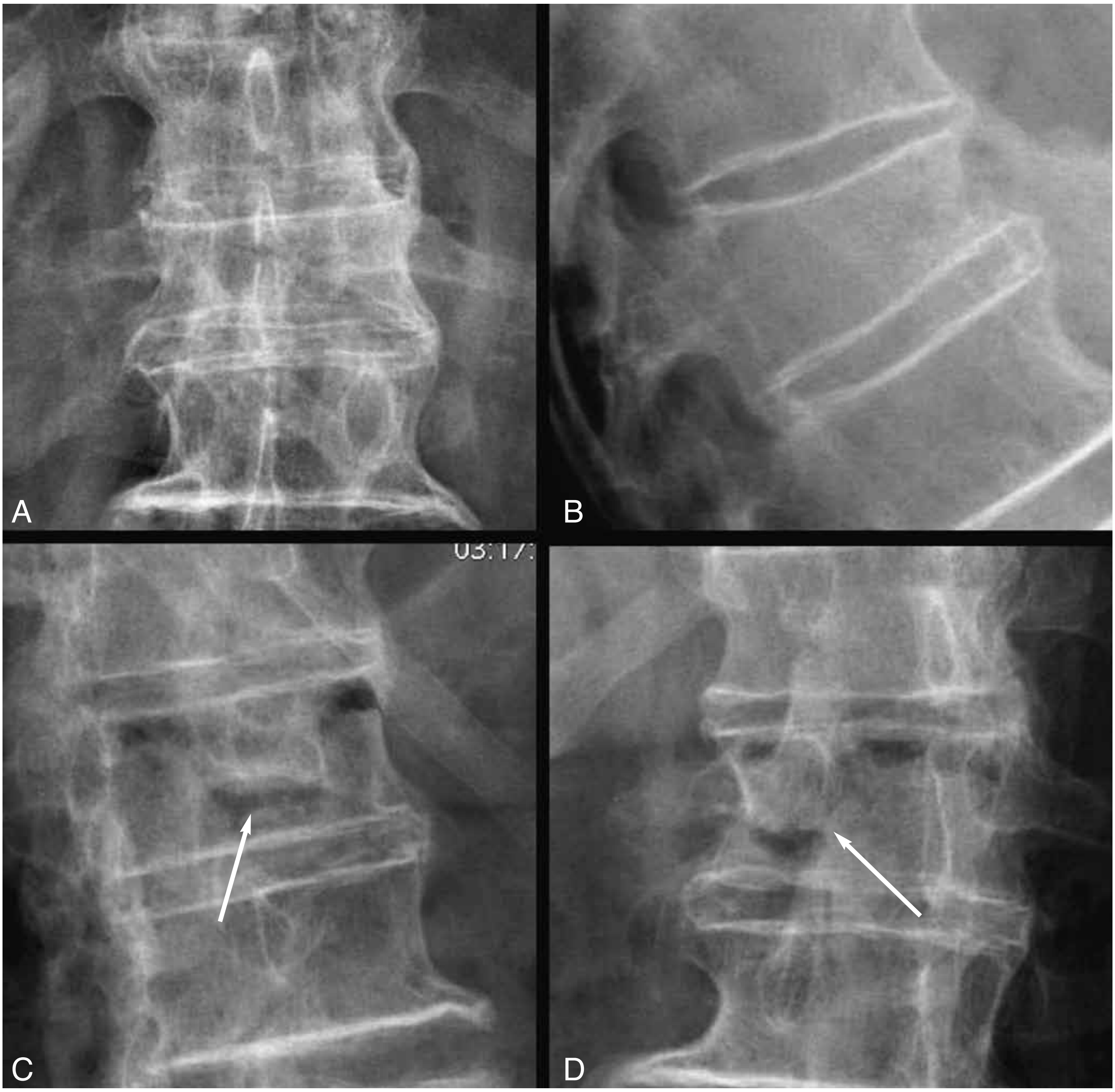

Fig. 4. — Case 2: A, B. Upright plain films of the thoraco-lumbar junction obtained just after the abdominal CT reveal an unambiguous collapse of about 40% of the vertebra T12.
Acute intravertebral vacuum spontaneously (white arrows) reappears on the oblique plain films (C, D) obtained in supine position during the same examination.

conclusion that VP is a dynamic process. Thus when synovial, discal or vertebral spaces are stretched, vacuum phenomenon may be produced acutely and transiently. This vacuum can secondarily progressively be replaced by gas which may persists some time (16). If distention persists gas may be progressively replaced by fluid.

Finally there is a question which remains unanswered in cases of ischemic vertebral collapses: where goes the vertebral gas and/or fluid – that has replaced the vacuum after prolonged supine position – when the collapsed vertebra is resubmitted to compression especially when a supine patient – with vertebral collapse – is mobilized in upright position. Probably this gas and/or fluid may be resorbed by the walls of the cleft. Nevertheless our two cases seem to illustrate that this gas and/or fluid could also in some conditions be forced towards the extravertebral spaces.

Finally some other questions remain unanswered:

– Why does the extravertebral extrusion of gas and/or fluid have not, to our knowledge, been reported before? The reason could be that, in clinical practice, only "snapshots" of the dynamic VP

Fig. 5. — Case 2: On a control CT performed one month later (A, B) extravertebral gas and fluid has disappeared but some gas persists in the vertebra. Fracture lines have progressed through the vertebral posterior arch and spinous process (black arrows). The patient was treated with percutaneous kyphoplasty (C, D).

are generally fortuitously found. Our rare and probably unpublished observations are thus probably also fortuitous. Systematic and prospective randomized dynamic studies – comprising an active mobilization of the patient – could eventually be able to depict all the sequences of this dynamic process but this condition is difficult to perform and/or justify in clinical practice.

– Does this phenomenon of extrusion of gas and/or fluid play a role in the painful symptoms presented by the two patients?

We conclude that, although rare, our observations seem to represent the illustration of a missing link in the cyclical dynamic continuum of the "vacuum phenomenon". These observations and these conclusions have to be corroborated by further studies.

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