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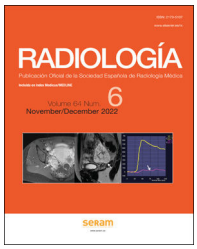

RADIOLOGY THROUGH IMAGES

The pathologies of migrants who travel by boat documented on imaging

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Pneumomediastinum;
Tuberculosis

Abstract The migration phenomenon is increasingly common worldwide. It is essential for radiologists to be aware of the endemic diseases of the migrant's country as well as the characteristics of the journey to be able to understand and interpret radiological findings when admitted to our centre.

This article aims to use imaging from our centre to describe the most common pathologies that migrant patients present with after long journeys by boat.

PALABRAS CLAVE
Migrante;
Patera;
Pie de patera;
Mano patera;
Mielinolisis central pontina;
Hipernatremia;
Neumotórax;
Neumomediastino;
Tuberculosis

La enfermedad de los migrantes que viajan en patera documentada en imagen

Resumen El fenómeno migratorio es cada vez más frecuente de manera mundial. Es fundamental conocer las enfermedades endémicas del país de origen del migrante y las características del viaje para poder entender e interpretar los hallazgos radiológicos a su llegada a nuestro centro.

Este trabajo tiene como objetivo revisar las patologías más frecuentes que presentan los pacientes migrantes tras realizar largos viajes en patera a través de imágenes radiológicas obtenidas en nuestro centro.

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Introduction

All over the world, people look for a better life through migration. According to the most recent estimates, there were approximately 281 million international migrants in 2020, 3.6% of the global population.[1] Many of these migrants are undocumented and arrive by boat on the coasts of Italy, Spain and Greece.[2] Record numbers are travelling the migratory routes from Africa to Europe, using the Canary Islands as the gateway onto the continent, and the number of arrivals may even surpass that of 2006.

In recent years, famine and extreme poverty have worsened due to population growth and the need to flee countries of origin due to violence fuelled by war; political, religious or sexual ideology; or the increasing threat of climate change. Many have sought to escape these scenarios and the accompanying conflict and persecution by embarking on a perilous journey on a precarious boat in an unsafe ocean.

The migrants' trek (from their points of origin) may involve several days of travel before they even reach the port from which they will later depart, setting sail on the next stage of their journey. This last voyage takes an average of four days if departing from Mauritania and nine days if departing from Senegal. Small boats or dugout canoes carry between 30 and 100 passengers in overcrowded spaces that limit any movement. The migrants are sometimes strapped down to stop them from falling overboard and they lack warm clothing and sufficient food and drink (Fig. 1). The small boat is equipped with an engine and global positioning system (GPS) which often fails, leading to adverse situations at sea. To avoid any extra weight which could cause the boat to sink, the travellers are frequently forced to bale out seawater which splashes on board from high waves.

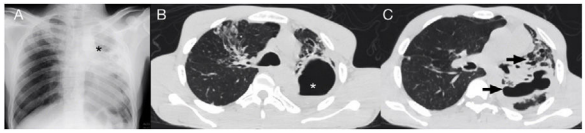

Figure 2 Twenty-seven-year-old male, with altered temperature sensation over last three days and general feeling of malaise after six-day journey on a small boat. (A) Chest radiograph, PA projection, showing reduced volume of the left hemithorax and cavitated consolidation in the left upper lobe (LUL) (black asterisk) suggestive of tuberculosis (TB). (B and C) Contrast-enhanced computed tomography (CT) in the lung window, axial slice (B and C), showing chronic cavitated consolidation (white asterisk) in LUL and left lower lobe (LLL) and bronchiectasis (black arrows). Post-primary tuberculosis ruled out microbiologically. In the end, the patient was diagnosed with a bronchiectasis superinfection.

This scenario leads to a set of uncommon diseases which radiologists and clinicians need to be aware of. Therefore, the aim of this article is to describe the diseases that have been witnessed by those who first examine these migrants.

Diseases identified in migrants

The first test carried out on migrants arriving by small boat is a radiograph of the hand to determine bone age. There is no specific protocol at our centre if migrants require hospi-

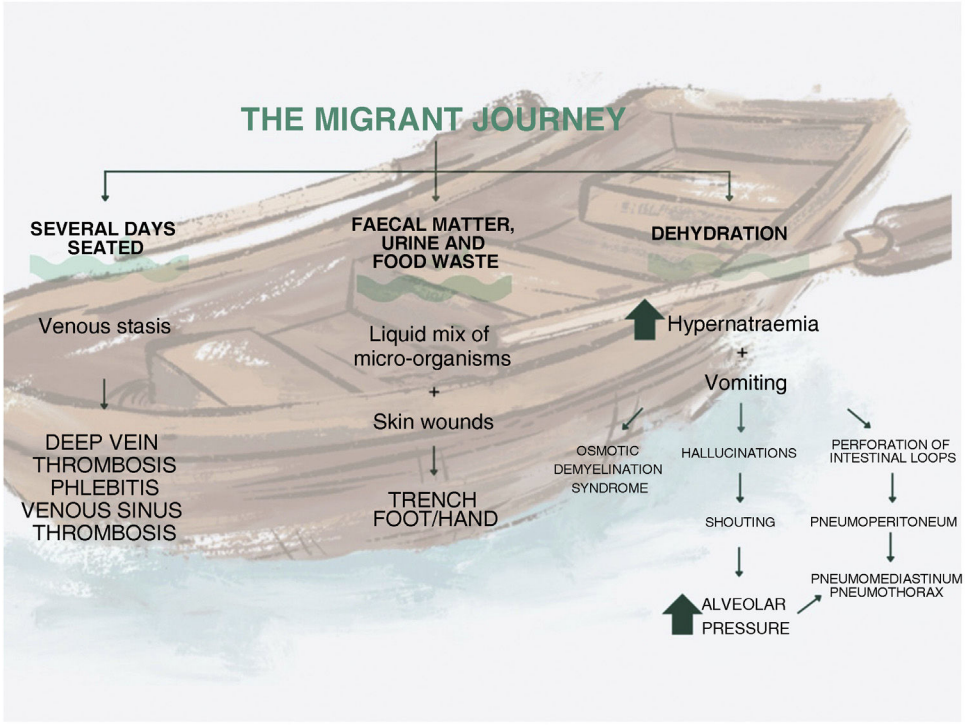

Figure 1 Summary of migrant journey.

Figure 3 Seventeen-year-old male, arrived on small boat with septic shock. (A) Chest radiograph, PA projection, showing bilateral consolidations mainly in lower areas, with normally positioned endotracheal tube. (B) Contrast-enhanced chest CT, axial slice, in lung window, showing peripheral airway blockage which is both bilateral and diffuse, as well as consolidations with peribronchovascular distribution (black arrows) which are mainly in lower lobes and probably infectious. Microbiological study confirmed pneumococcus and *Pseudomonas aeruginosa*. (C) Follow-up axial CT of the chest in the lung window after 10 days showing resolution of the lower consolidations and the appearance of consolidations (black arrows) and areas of ground glass (black asterisk) in the upper lobes, compatible with a pattern of organised pneumonia.

talisation. Rather, different diagnostic tests are requested in line with the clinical suspicions.

Thoracic diseases

Infectious lung diseases

These patients often come from countries which have infectious diseases that have almost been eradicated in our area due to the preventative measures at our disposal.[3–5] One of these diseases is tuberculosis,[4,5] both in its primary and postprimary forms. Another infectious lung manifestation commonly seen among these patients is pneumonia, in both its bacterial and viral forms, due to low rates of vaccination coverage in the countries of origin[6] (Figs. 2 and 3).

It is important to remember that the previously weakened immune systems of migrants, low vaccination rates in the countries of origin[6] and overcrowding on the boats predispose them to disease transmission.

Spontaneous pneumomediastinum and subcutaneous emphysema

An absence of food and water leads to dehydration which in turn can cause hypernatraemia and associated nausea and vomiting during the crossing. This may lead to the Macklin effect,[7–9] named after the author who experimentally demonstrated its pathophysiology in 1939. It involves three specific steps:[7,8] alveolar rupture secondary to a rise in intra-alveolar pressure, air dissection along bronchovascular sheaths and the spreading of this pulmonary interstitial emphysema into the mediastinum. Subsequently, air may diffuse to subcutaneous planes and through the abdominal aponeurotic sheaths to the peritoneum and retroperitoneal space. The Macklin effect can be confirmed on computed tomography (CT) when the scans reveal collections of air dissecting the bronchovascular sheaths. These findings are described for more than 89% of spontaneous pneumomediastinum patients[7,8,10] and are much more common than a type of pneumomediastinum that is secondary to oesophageal or tracheal rupture.

It is rarely associated with pneumorrhachis, pneumothorax or pneumopericardium. Isolated pneumorrhachis is uncommon.[11] It can be extra- or intradural, with extradural pneumorrhachis more commonly associated with pneumomediastinum (Fig. 4).

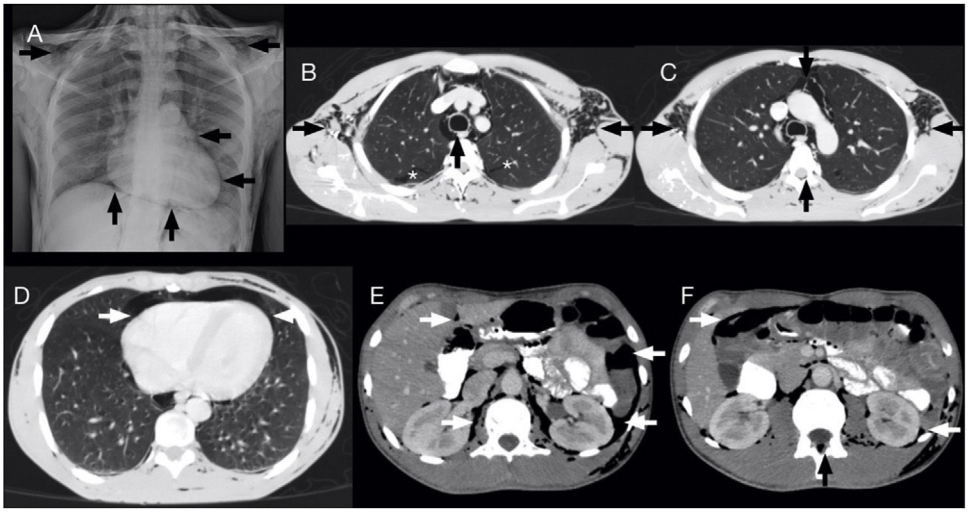

Figure 4 Fifteen-year-old male, arrived on small boat, admitted for necrotising fasciitis of the right ankle. Chest radiograph performed by protocol showing accidental finding of subcutaneous emphysema, pneumomediastinum and pneumoperitoneum (A). Chest CT in lung window confirms the Macklin effect with linear collections of air dissecting the bronchovascular sheath (white asterisks) in both upper lobes (B), associated with subcutaneous emphysema and pneumomediastinum (B and C), pneumorrhachis (black arrows) (C) and pneumopericardium (white arrows) (D). CT of the abdomen in soft tissue window showing pneumoperitoneum and retropneumoperitoneum (white arrows) (E and F), confirming the presence of pneumorrhachis (black arrow) at several levels (black arrow) (F).

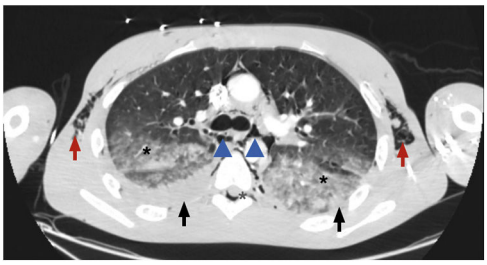

Figure 5 Migrant man who fell overboard. Presenting with fever, dyspnea and dehydration. Request made for chest CT with intravenous contrast administration. (A) Axial slice in lung parenchyma window showing signs of alveolar ground glass consolidations (black asterisk) prone to consolidation (black arrows) in both sides of the chest as well as subcutaneous emphysema (red arrows), pneumomediastinum (blue arrowhead) and pneumorrhachis (grey asterisk). The findings suggest drowning with a possible superinfection (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Drowning

On some occasions, we may encounter migrants who have experienced drowning. Thoracic CT images in these cases can vary widely ranging from completely normal to showing generalised pulmonary oedema with diffuse lung involvement.

The most characteristic appearance of this consists of bilateral alveolar opacities and areas of ground glass (Fig. 5), often involving perihilar consolidation while not affecting the lateral regions. While involvement is typically bilateral, it can be predominantly unilateral at times. This pattern tends to worsen during the first 24–48 h and resolves over three to five days. However, a bacterial superinfection or overlapping respiratory distress may prolong these findings. There may also be related interstitial thickening which presents as a crazy-paving pattern.[12]

Therefore, it is important for radiologists to be familiar with the pathophysiology of this common cause of pneumomediastinum in order to avoid unnecessary diagnostic and therapeutic interventions. The clinical course usually progresses quickly and benignly, reaching spontaneous resolution.

Abdominal disease

Pneumoperitoneum

There are many causes of pneumoperitoneum: perforation of a hollow viscus by a preexisting ulcer[13] (Fig. 6);

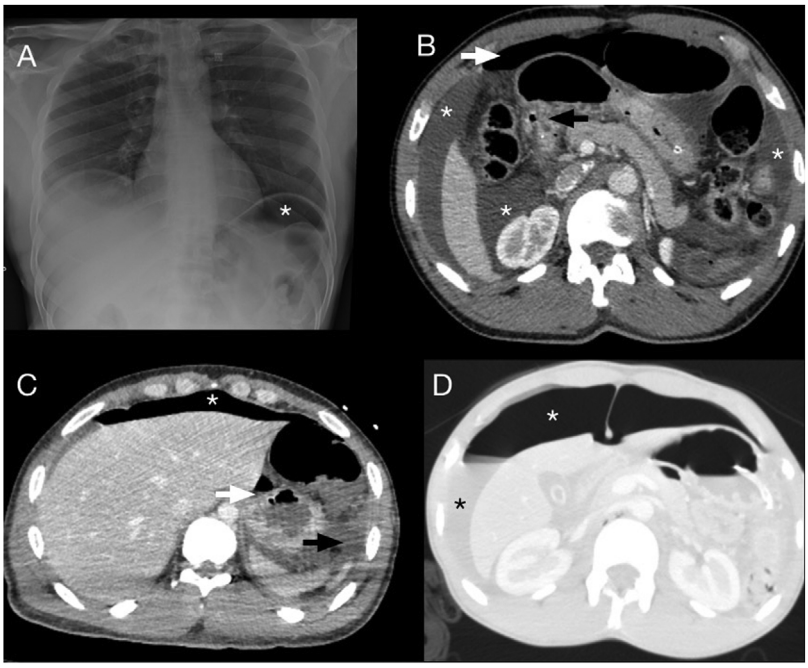

Figure 6 *Case 1:* Forty-year-old male, arrived on small boat with acute abdominal pain, hypotension, tachycardia, and elevated lactic acid. (A) Radiograph of chest/abdomen which shows pneumoperitoneum (white asterisk). (B) Contrast-enhanced CT showing pneumoperitoneum (white arrow), abundant free fluid (white asterisk) and perforation in first portion of the duodenum (black arrow), likely related to a perforated ulcer, confirmed in surgery. *Case 2:* Thirty-year-old male, arrived on small boat, admitted for septic shock, with free fluid visible in abdominal ultrasound. (C) CT showing a perforated posterior gastric wall (white arrow) as well as abundant pneumoperitoneum (white asterisk) and free fluid (black arrow). *Case 3:* Sixteen-year-old male, arrived on small boat, with syncope, recovered cardiorespiratory arrest and abdominal distension. (D) CT shows abundant pneumoperitoneum (white asterisk) and free fluid (black asterisk) with no sign of gastrointestinal perforation. Postpyloric perforation observed during surgery.

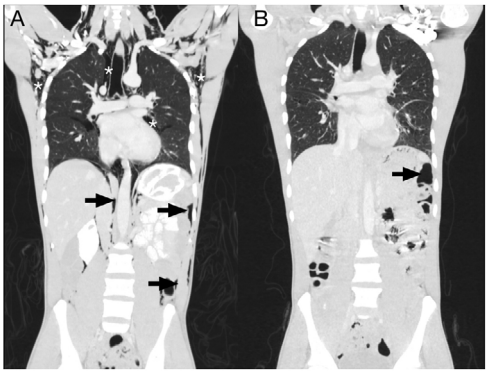

Figure 7 Fifteen-year-old male, arrived on small boat, presenting with abdominal pain, coffee ground vomiting, fever and dehydration. CT is performed and shows pneumoperitoneum (black arrows) and no gastrointestinal perforation. There is also abundant pneumomediastinum, pneumopericardium and subcutaneous emphysema (white asterisks). In follow-up CT, after a week of conservative management, significant improvement observed.

spread of pneumomediastinum secondary to oesophageal perforation caused by vomiting (Boerhaave syndrome); or spontaneous perforation secondary to *Vibrio parahaemolyticus* infection,[14] which is found in seawater. These causes explain the high number of cases observed among these patients, and they are worsened by the unfavourable conditions during the crossing (including days without drinking fresh water, consumption of seawater and stress).

Other causes of pneumoperitoneum should also be considered when there is no evidence of gastrointestinal perforation (Fig. 7) such as the coexistence of pneumothorax/pneumomediastinum—the Macklin effect—,[7–9] sepsis originating in the lungs, cardiopulmonary resuscitation or unknown causes.[15–17]

Therefore, it is important to note that there will not always be a visible cause for pneumoperitoneum that will explain its presence.

Vascular disorders

In many cases, the state of shock experienced by patients leads to coagulation issues which can in turn lead to intestinal ischaemia, as in the case presented in Fig. 8 which features bilateral kidney involvement due to renal vessel thrombosis.

Hypoperfusion can also be secondary to dehydration and is characterised by the following findings on CT: reduced aortic calibre, collapse of the inferior vena cava, thickening of the intestinal wall with increased mucosal enhancement, reduced splenic volume with hypodensity, hyperenhancement of the adrenal glands, hyperenhancement of the kidneys and ascites.

Neurological disease

Osmotic demyelination syndromes

Dehydration and the ingestion of seawater lead to severe hypernatraemia.[18] Modifications to sodium levels in the blood can lead to the onset of an osmotic demyelination syndrome.[18–20] This has traditionally been associated with alcoholic patients and those with hyponatraemia who undergo rapid fluid replacement. However, it has now been shown to occur in other scenarios, including in situations of significant changes in blood osmolarity, such as in our cases.

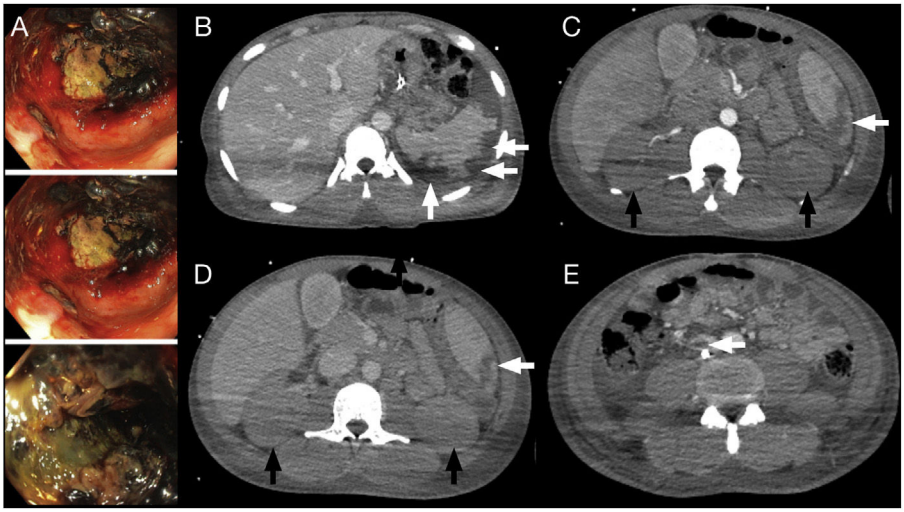

Figure 8 Twenty-three-year-old male migrant, with septic shock and acute renal failure. Colonoscopy also showed rectorrhagia and ischaemic colitis (A) and there were doubts around whether or not there was perforation. Therefore, a contrast-enhanced CT of the abdomen/pelvis was performed in the portal phase with images revealing no signs of perforation. They did however show: (B–D) Splenic infarcts. C and D) Overall low levels of enhancement of both kidneys both in the arterial and portal phases, suggestive of renal ischaemia (black arrows). (E) Contrast-enhanced CT of the abdomen/pelvis in the portal phase shows a central venous catheter in the inferior vena cava with adherent thrombus (white arrow).

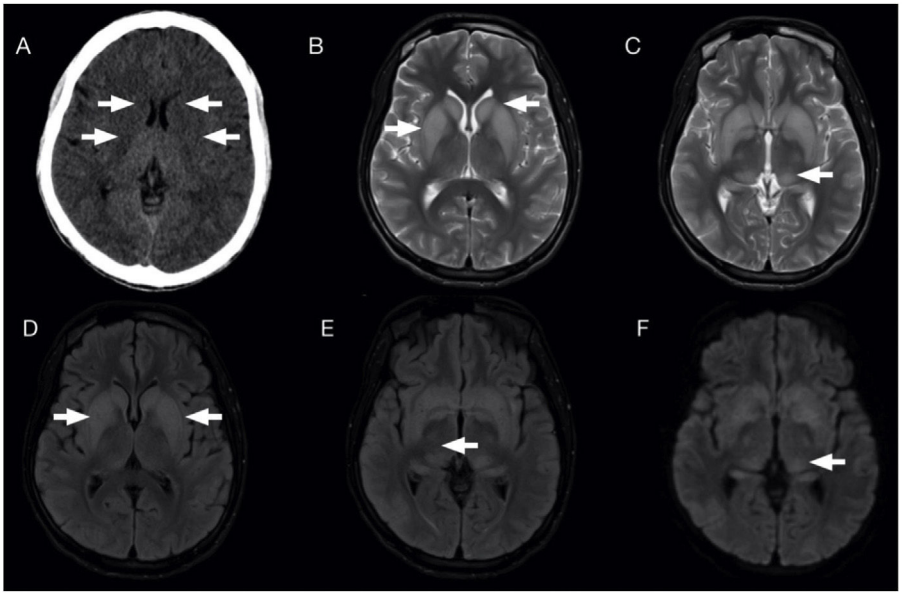

Figure 9 Thirty-three-year-old male, with hypernatraemic dehydration and impaired consciousness, admitted upon disembarking from small boat. Non-contrast brain CT shows areas of hypodensity and dedifferentiation which affect both the caudate and lentiform nuclei bilaterally and symmetrically (white arrows) (A). The MRI performed later confirmed the existence of areas of signal hyperintensity in caudate and lentiform nuclei in the T2-weighted (B and C) and FLAIR (D and E) sequences as well as in the posterior margins of both thalami (C and E), with hyperintense signal in diffusion-weighted images (F) in which no restriction was seen on the ADC map nor enhancement after contrast administration.

Due to water-electrolyte imbalances, other migrants may suffer from various forms of encephalopathy which produce visual hallucinations.

Clinical symptoms include tetraplegia, pseudobulbar palsy and acute changes in level of consciousness that can lead to coma and death if undiagnosed.[18–20]

The most common way in which these syndromes present is central pontine myelinolysis, in which there is symmetrical demyelination centred mainly in the central region of the pons.[21] There are also cases of extrapontine myelinolysis,[22] in which similar symmetrical changes occur in extrapontine locations including the cerebellar white matter, thalami, globus pallidus, putamen and lateral geniculate bodies.

In terms of diagnostic tests, the first is usually a head CT scan which may show changes in the density of the basal ganglia and a hypodense area in the pons.[12]

However, Magnetic Resonance (MRI) is the best diagnostic test due to its greater levels of sensitivity when it comes to detecting typical lesions[21,22] (Fig. 9), which are usually bilateral and symmetrical in the central region of the pons in the case of central pontine myelinolysis, and in the locations previously described for extrapontine myelinolysis. The lesions are hyperintense on T2-weighted and FLAIR sequences and hypointense on T1-weighted sequences, with no enhancement following gadolinium administration. Lesions may sometimes appear at a later date. Therefore, if the clinical scenario is compatible, this disease should continue to be considered for 10–14 days after the onset of symptoms, even if the initial diagnostic test results are normal.

It is important to note that electrolyte changes are very common among these patients, so other causes should also be explored.

Infections in upper and lower limbs

Infectious skin conditions can be caused by bacteria that enter through millimetric gaps, leading to painful cellulitis. At times this progresses to form deep abscesses and even tissue necrosis.[23] In some advanced cases, the response to surgical debridement and antimicrobial drugs is insufficient, resulting in amputation.

When the foot is affected, it is known as trench foot (or ''*pie de patera*'' (dinghy/raft/boat foot) in Spanish) (Figs. 10–12). This condition results from the feet being in contact with the water that splashes into the boat, vomit from the passengers, rotten food waste, faecal matter and urine. All this, combined with high temperatures in the day and low temperatures at night means that microorganisms enter through wounds more easily. There are also some intrinsic factors such as race and age (the skin of younger patients offers less protection) that facilitate the pathogenesis of the process.[23,24] Nevertheless, ethnicity can also act as a protective factor for this disease, as in the case of North African immigrants.[23]

The most commonly cultivated germs[23,24] in the skin samples are *Staphylococcus aureus, Streptococcus dysgalactiae* and *Shewanella algae*, while colonies of *Vibrio alginolyticus*

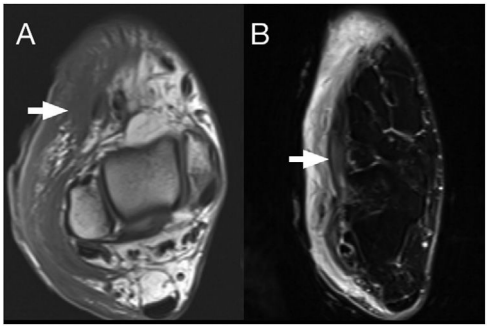

Figure 10 Forty-year-old patient, admitted after disembarking with severe hypernatraemic dehydration, acute renal failure and signs of rhabdomyolysis. Presents with oedema of the right leg. Contrast-enhanced MRI performed to rule out collections and osteomyelitis with a focus on axial T1-weighted sequences and axial fat-saturated proton density-weighted sequences as well as fluid in subcutaneous fat (white arrow) and discreet oedema in local musculature (white arrow) with no collections, compatible with trench foot.

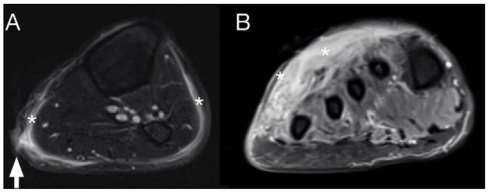

Figure 11 Thirty-one-year-old patient, referred 24 h after disembarking from small boat, with hypoglycaemia symptoms and pain in left leg and right arm. Physical examination determined extensive oedema in the left side of the pretibia with blistering, while oedema and ulcers observed in the calf region, and oedema and redness of the right hand. Diagnosis of rhabdomyolysis and cutaneous-onset sepsis and MRI requested. Axial fat-saturated T2-weighted images of the middle third of the leg (A) and distal third of the foot (B) showing increase in subcutaneous intensity due to the presence of subcutaneous fluid, and in the superficial fascia (white asterisks) with no associated collections or fluid in deep fascia, with broken skin in middle calf region.

are also present at times. The pathophysiological mechanism that could make these infectious conditions more likely involves a limb suffering from subacute ischaemia due to pressure and deficient venous drainage during the journey's cramped conditions (having to remain seated for several days), or an engine burn or a cut. Secondary internal inflammation causes tissue expansion against young inelastic skin, worsening ischaemia and leading to necrosis, probably through some kind of compartmental mechanism.

The same clinical features have also been seen in upper limbs, in what is also known as trench hand or ''*mano de patera*'' (dinghy/boat hand) in Spain.

There have been recent reports of sterile necrotising cellulitis in migrants.[25] This involves massive oedema of the extremities and is associated with necrosis of the subcutaneous cellular tissue and skin. It does not affect the muscles and its aetiology is non-infectious. It has been suggested that

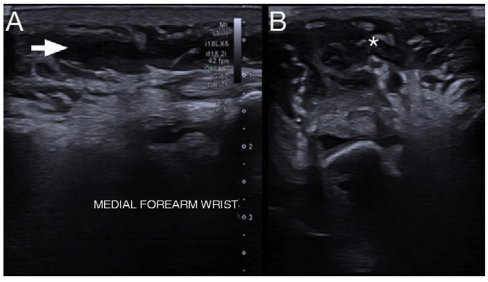

Figure 12 Thirty-two-year-old male, who had disembarked the previous day, presenting with pain in left hand and severe dehydration after nine days at sea. Patient is admitted with clinical symptoms of severe hypernatraemia, metabolic acidosis, rhabdomyolysis and acute renal failure. Presenting with oedema in left arm and septic symptoms with cellulitis in left arm and ulcers on back. Ischaemic lesions on toes due to thrombotic microangiopathy. Decision is made to carry out ultrasound of the forearm and hand (A and B) to rule out presence of collections, observing fluid in subcutaneous fat (white asterisk) on the back of the palm of the hand which has spread to forearm. Findings compatible with trench hand.

the cause may be inflammation secondary to the osmotic effect that comes from ingesting seawater and/or aggressive fluid replacement at hospitals.

It is important to note that trench foot/hand is a severe problem and swift action must be taken to avoid serious consequences such as amputation.

Vascular disease

Deep vein thrombosis

This is often suffered by patients who are dehydrated and who have been sat in the same position for days, having been unable to move around. This easily leads to venous stasis and deep vein thrombosis (Fig. 13).

Conclusion

This article has described several diseases that are likely to be suffered by migrants when crossing to Europe in small boats under precarious conditions. This health situation is on the rise in Spain and it is therefore important

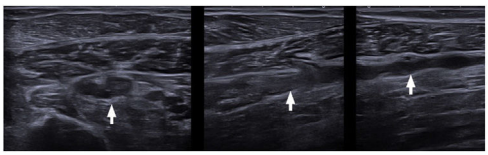

Figure 13 Twenty-seven-year-old male, with oedema of right leg and elevated D-dimer, admitted after disembarking from small boat. Doppler ultrasound performed in which the posterior tibial vein is blocked (white arrows) by a thrombus.

that radiologists be familiar with the main imaging findings so that patients can be managed in an efficient manner.

Author contributions

Drafting, concept and design, information gathering and review: M. Luisa Nieto Morales and Cristina Candelaria Linares Bello.

Information gathering and drafting: Yasmín El Khatib Ghzal and Sonia Benítez Rivero.

Design and review: Mónica Fernandez del Castillo Ascanio and Carla Souweileh Arencibia.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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