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## PICTORIAL ESSAY

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# Imaging in *Salmonella* spp. Infection

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### ABSTRACT

*Salmonella* spp. cause a broad spectrum of human illnesses, including gastroenteritis, typhoid fever, and bacteraemia with or without extraintestinal focal infections, or may be present in an asymptomatic carrier. This pictorial essay aims to illustrate the various manifestations of culture-proven *Salmonella* infection in enteric fever and, particularly, in extraintestinal focal infections, which is one of the predictors for mortality.

**Key Words:** Aneurysm, infected; *Salmonella* infections; Typhoid fever

## 中文摘要

### 沙門氏菌感染的影像

呂沛欣、李嘉樂、譚家盈、陳澤宗

沙門氏菌可以引致各種疾病，包括腸胃炎、傷寒、伴或不伴腸道外局灶感染的菌血症，亦可表現為無症狀攜帶者。本文旨在附圖說明經細菌培養證實的沙門氏菌感染誘發的傷寒，尤其是伴發腸道外局灶性感染（死亡預測因素之一）的病例的各種臨床表現。

### INTRODUCTION

*Salmonella* is a genus of bacteria that are a major cause of foodborne illness throughout the world. More than 2500 serotypes have been identified. Current estimates indicate that 93.8 million cases of gastroenteritis due to *Salmonella* spp. occur globally each year, with about 155,000 salmonellosis-related deaths each year.<sup>1</sup>

*Salmonella* infections in humans are divided into enteric fever caused by *Salmonella enterica* serotypes Typhi and Paratyphi A, B, or C (referred to here as *S. typhi* and *S. paratyphi*), and diverse presentations caused by a large number of non-typhoidal *Salmonella* serovars (NTS). Typhoid only occurs in humans but it has little

association with compromised immunity. In contrast, NTS have a broad vertebrate host range, and have a dramatically more severe and invasive presentations in immunocompromised adults, in particular in the context of human immunodeficiency virus,<sup>2</sup> which is a growing health threat to both developing and developed countries. NTS lead not only to self-limiting acute gastrointestinal infections, but also to bacteraemia with or without extraintestinal focal infections.<sup>3</sup> Advanced age and extraintestinal organ involvement are predictors for mortality.<sup>3</sup>

This pictorial essay illustrates the various manifestations of *Salmonella* infection in enteric fever and, particularly,

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in extraintestinal focal infections using different imaging modalities. Images of mycotic aneurysms after diverse surgical interventions are also shown. In complicated or fulminant *Salmonella* infection, the key to successful treatment lies in early radiological recognition and diagnosis. Familiarisation with the imaging spectrum by radiologists may therefore facilitate timely antibiotic or surgical intervention, and thus help minimise morbidity and mortality.

### ENTERIC FEVER

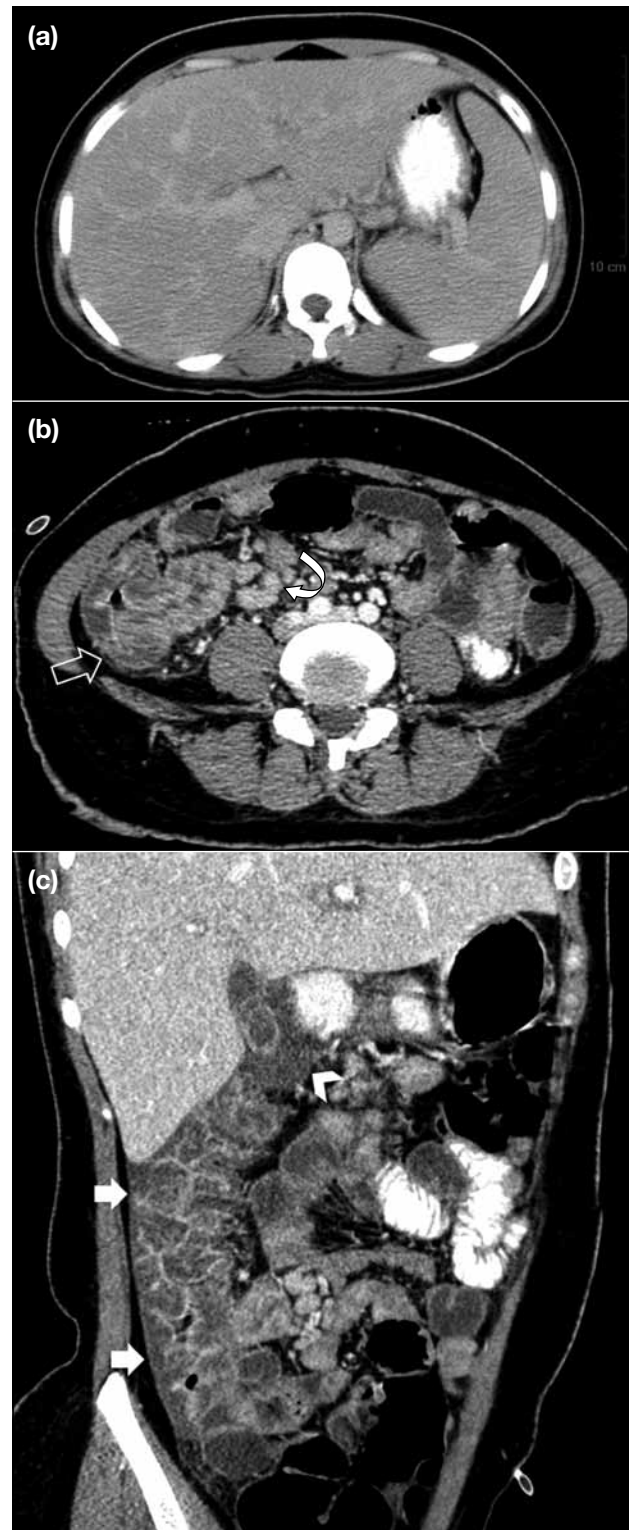
Enteric fever is an acute febrile illness caused by *S. typhi* and *S. paratyphi* through consumption of contaminated water or food. Symptoms include high fever, malaise, headache, constipation or diarrhoea, rose-coloured spots on the trunk, and hepatosplenomegaly (Figure 1a). In uncomplicated cases, the radiological manifestations are confined to the terminal ileum and caecum, where the organisms are phagocytosed by lymphoid tissue, particularly in the Peyer's patches of the terminal ileum and the smaller lymph follicles in the caecum.<sup>4</sup> Symmetric and homogeneous wall thickening of the ileum, both ileum and caecum (Figures 1b and 1c), or only the right-sided colon with sparing of the ileum may be observed.<sup>5</sup> Adjacent mesenteric lymphadenopathy (Figure 1b) and non-specific gallbladder wall thickening (Figure 1c) may be present.

### EXTRAIESTINAL FOCAL INFECTIONS

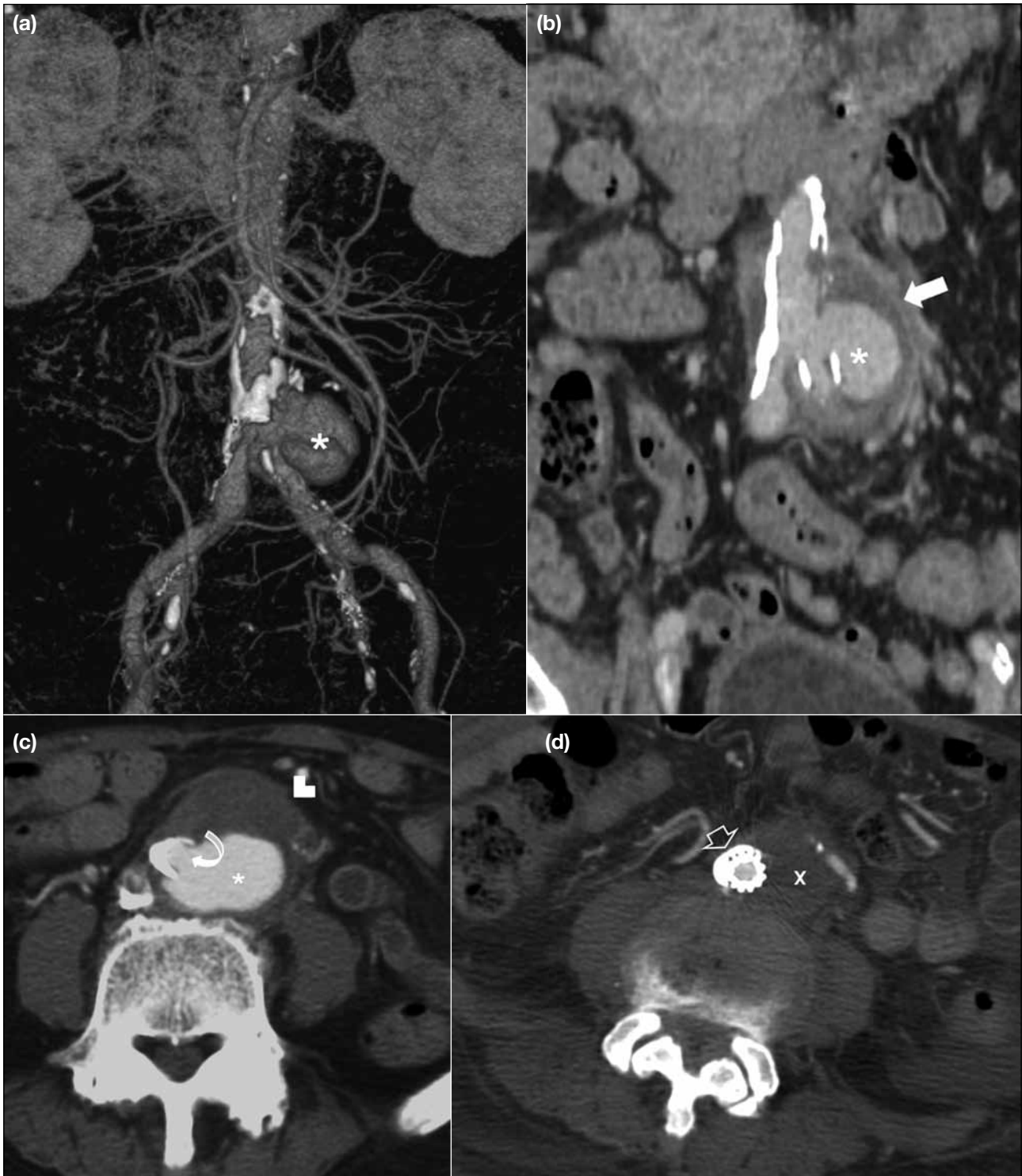
#### Cardiovascular System

The cardiovascular system is a typical, although rare, site of involvement by non-typhoidal *Salmonella* disease.<sup>6</sup> *Salmonella* infection remains one of the most common causes of infected aneurysms. *S. enterica* is unique in its propensity to adhere to damaged endothelium of the heart and arterial walls,<sup>6</sup> causing endocarditis and mycotic aneurysm. The most frequent site is the abdominal aorta, more precisely, its infrarenal segment, followed by the thoracic aorta. Other arteries — such as the iliac, popliteal, carotid, and coronary arteries, and arteriovenous fistulae and Dacron aortofemoral bypass grafts — are occasionally involved.<sup>6</sup> Mediastinitis, pericarditis, and device-related infections associated with pacemakers and defibrillators have also been reported.<sup>6</sup>

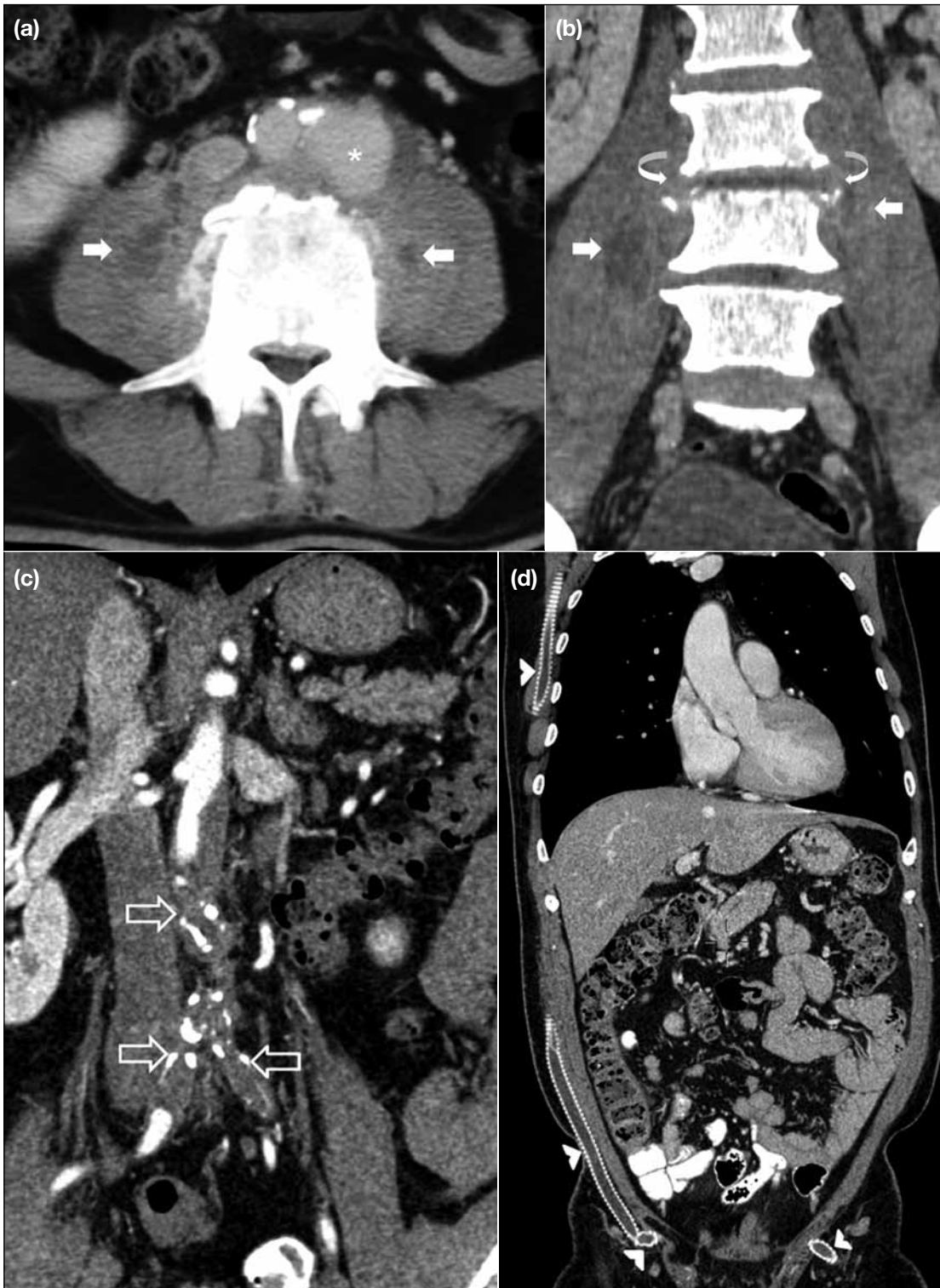
Computed tomography (CT) findings suggestive of mycotic aneurysm include saccular aneurysm (Figures 2a and 3a), periaortic soft tissue mass with rim enhancement (Figures 2b and 3a), disruption of



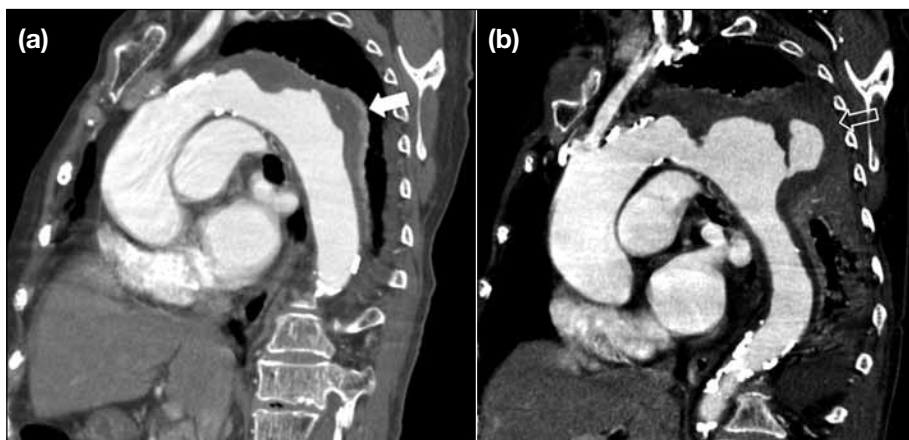
**Figure 1.** A 22-year-old woman with typhoid fever confirmed by Widal test and blood culture yielding *Salmonella typhi*. Axial post-contrast computed tomography shows (a) hepatosplenomegaly, and (b) oedematous ileocaecal junction (hollow arrow) with pericolonic inflammatory fatty stranding and enlarged mesenteric lymph nodes (curved arrow). (c) An oblique coronal reformatted post-contrast image shows long segment bowel wall thickening of the right-sided colon (arrows) due to colitis, gallbladder wall thickening (arrowhead) and hepatomegaly.



**Figure 2.** Computed tomography images of an 81-year-old man with *Salmonella* bacteraemia and left distal abdominal aortic mycotic aneurysm that was treated by endovascular aortic repair. (a) A 3-dimensional reformatted aortogram shows a saccular aneurysm (asterisk) at the distal aorta; (b) an oblique coronal reformatted image shows a saccular aneurysm (asterisk) at the distal aorta, with periaortic inflammatory soft tissue with rim enhancement (arrow); (c) an axial image shows disruption of intimal calcification (curved arrow) by the saccular aneurysm (asterisk) with periaortic inflammatory soft tissue (arrowhead); and (d) a follow-up aortogram shows a thrombosed aneurysmal sac (x) and the endovascular aortic stent (hollow arrow).



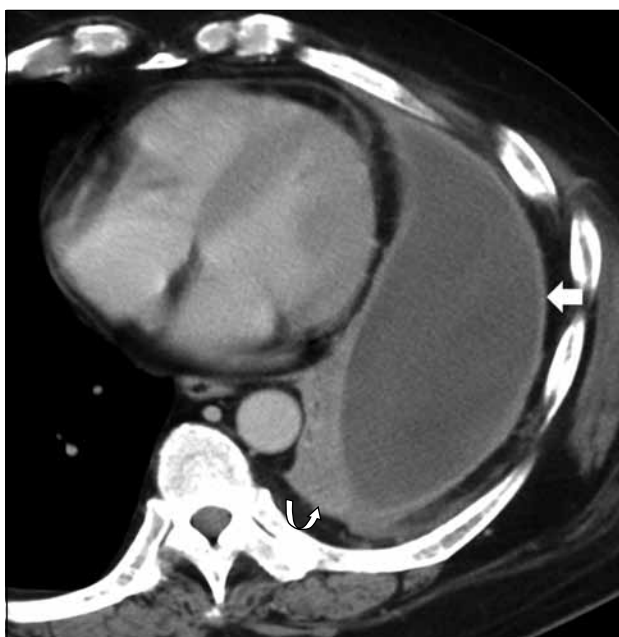
**Figure 3.** Computed tomography images of a 51-year-old man with *Salmonella* infective endocarditis, infrarenal aortic mycotic aneurysm, bilateral psoas abscesses, and infective spondylodiscitis. Blood culture yielded *Salmonella enteritidis*. The patient was treated by surgical resection of the infected aneurysm with aortic ligation and axillofemoral vascular bypass. (a) An axial post-contrast image shows a saccular aneurysm (asterisk) arising from the left side of the distal aorta with periaortic inflammatory soft tissue and fatty stranding and rim-enhancing fluid collections within the bilateral psoas muscles (arrows); (b) a coronal reformatted image shows bilateral rim-enhancing psoas abscesses (arrows) and infective spondylodiscitis of the adjacent lumbar spine with endplate irregularity and fluid within the intervening disc space (curved arrows); (c) a coronal oblique reformatted image shows postoperative thrombosis of the distal aorta and bilateral common iliac arteries (hollow arrows); and (d) a follow-up coronal contrast image 1.5 years after surgical intervention shows the complication of axillofemoral bypass — graft thrombosis (arrowheads) with absence of intraluminal contrast flow within the grafts.



**Figure 4.** Sagittal oblique reformatting images of computed tomographic aortogram of a 79-year-old woman with *Salmonella* bacteraemia and interval enlarging aortic arch aneurysm and newly developed saccular aneurysm. (a) An image shows a fusiform aortic arch aneurysm (arrow) with eccentric mural thrombus; and (b) a follow-up image 5 days later shows an interval enlarging arch aneurysm and a newly developed saccular aneurysm (hollow arrow) at the descending aortic arch.

intimal calcification (Figure 2c), para-aortic gas, rapid development of an aneurysm (Figure 4), and adjacent vertebral destruction (Figure 3b).<sup>7</sup> Adjacent psoas abscess formation may also be observed (Figures 3a and 3b).

Traditionally, aggressive surgical resection, debridement of infected periaortic tissues, and reconstruction of the aortic flow by anatomic or extra-anatomic techniques (Figures 3c and 3d) are the gold standard for treatment of infected aneurysms. However, these techniques are associated with high surgical morbidity and mortality.<sup>8</sup>



**Figure 5.** A post-contrast computed tomography image of the thorax of a 54-year-old man with recurrent left empyema, and *Salmonella enteritidis* in the pleural aspirate, showing a rim-enhancing left pleural effusion (arrow) with a collapsed left lower lobe of the lung (curved arrow).

A complication of extra-anatomic axillofemoral bypass, graft thrombosis, is shown in Figure 3d.

Endovascular aortic repair (EVAR) provides a less invasive alternative technique with favourable results for the management of infected aortic aneurysms, on a selected basis. Despite its use for the past two decades, its acceptability remains controversial.<sup>8</sup> Figure 2d illustrates a successful EVAR with complete thrombosis of the aneurismal sac.

### Pleuropulmonary System

Pneumonia and, less commonly, empyema (Figure 5) account for about 10% of extraintestinal focal infections.<sup>3</sup> Pneumonia usually presents as lobar infiltrates or, less commonly, a patchy diffuse infiltrate. There is no distinguishing characteristic to differentiate *Salmonella* pneumonia from other acute bacterial pneumonia.<sup>9</sup> Lung abscesses have also been reported.<sup>9</sup>

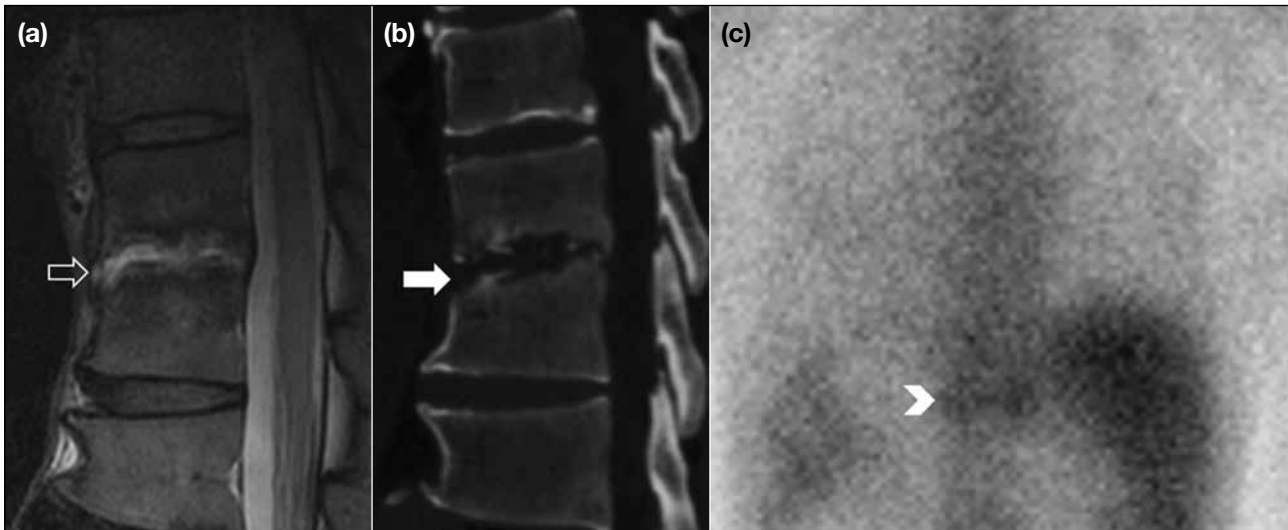
### Hepatobiliary and Splenic System

The spleen, liver, and gallbladder are common sites of intra-abdominal salmonella infection, ranging from non-specific organomegaly (Figure 1a) to abscess formation. Calculus and acalculous cholecystitis and, less frequently, cholangitis are recognised manifestations of salmonellosis.<sup>9</sup>

### Spine and Spinal Cord

The spine is a commonly affected site in *Salmonella* osteomyelitis, by either haematogenous or contiguous spread.<sup>10</sup>

Magnetic resonance imaging (MRI) is an accurate tool for detecting abnormal signals in involved adjacent vertebrae, intervening disc (Figures 6a, 7a, and 7b), and



**Figure 6.** Magnetic resonance, computed tomography and gallium scan images of a 61-year-old man with recurrent *Salmonella* bacteraemia and infective spondylodiscitis at T11/12. (a) A sagittal T2-weighted magnetic resonance image (repetition time 3303 ms/echo time 120 ms) shows abnormal fluid signal within the corresponding disc and T2-weighted hyperintense endplates with erosions (hollow arrow); (b) a sagittal reformatted computed tomography image in bone window shows endplate erosion and disc space narrowing (arrow) at the T11/12 level; and (c) a gallium scan using gallium-67 citrate (posterior planar view) shows a moderate transverse increase in uptake at the T11/12 level (arrowhead).

associated paraspinal soft tissue infections. Associated myelitis of the spinal cord is a rarely reported manifestation (Figure 7a).

CT can detect bone and endplate destruction (Figure 6b), disc disease (Figure 3b), paravertebral abscesses (Figure 3a), and aortic aneurysms, which is particularly useful for patients with contraindications for MRI. Osseous instability and neurological compromise (e.g. epidural abscess) may be present, for which surgical intervention may be necessary.

The use of radionuclide imaging such as Gallium scan for infection (Figure 6c) and white blood cells scan may help to localise the site of infection. The osteoblastic activity in osteomyelitis elicits intense uptake in <sup>99m</sup>technetium methylene diphosphonate bone scan (Figure 7c).

### Musculoskeletal System

*Salmonella* osteomyelitis has a well-known association with sickle cell disease. Septic arthritis is another manifestation of focal *Salmonella* infection. It most commonly involves knee, hip, and shoulder in descending prevalence.<sup>9</sup> Joint effusion with enhancing synovial thickening may be appreciated on CT (Figure 8a) or MRI. In some cases, focal demineralisation of adjacent bone or osteolytic lesion may be observed. Ultrasonography is useful for detecting joint effusion,

and sometimes echogenic debris within (Figure 8b), and thus guides needle aspiration for microbiological diagnosis. Other manifestations include periosteitis and abscess formation.<sup>5</sup>

### Central Nervous System

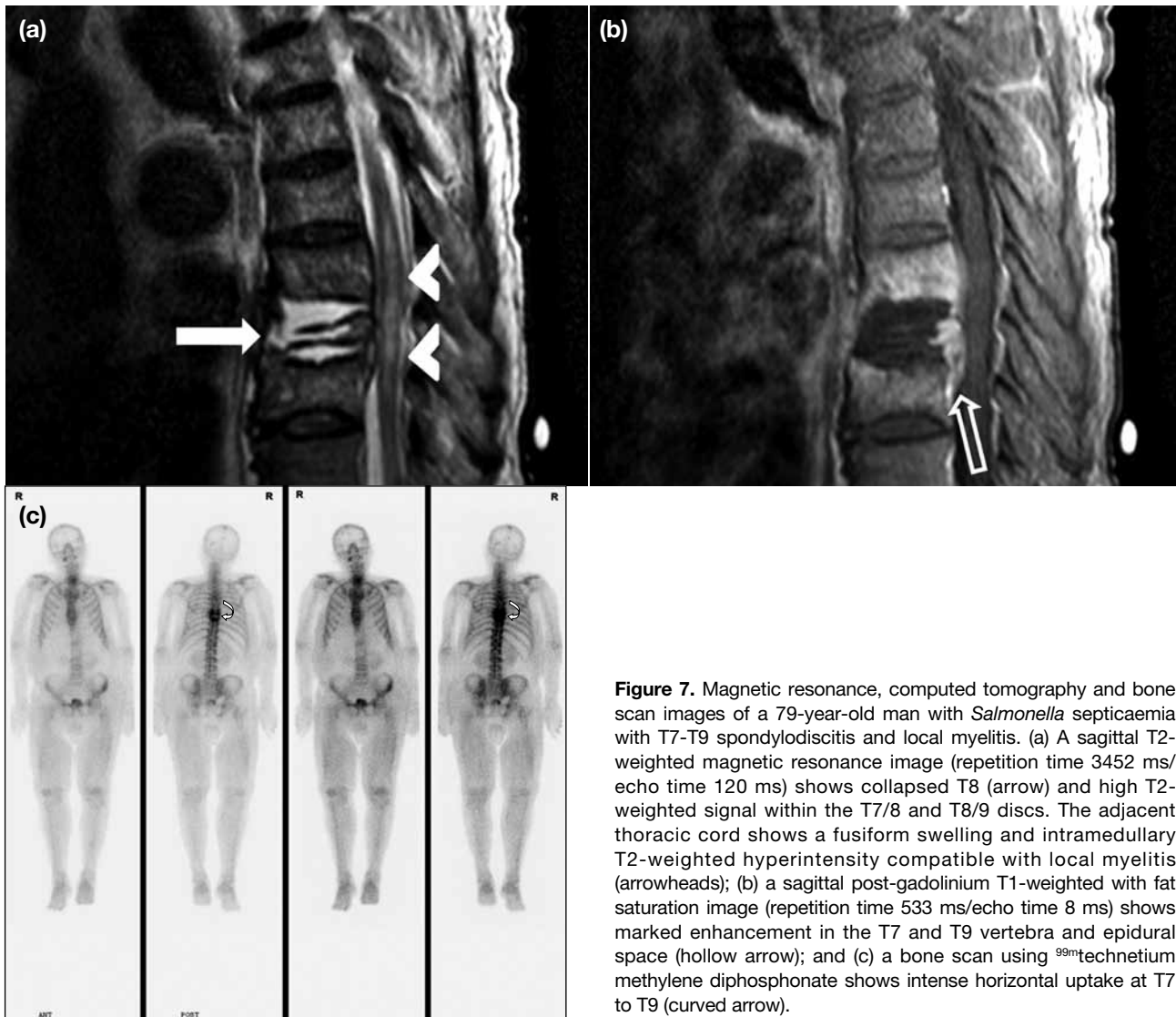
*Salmonella* meningitis occurs more commonly in young children, especially in the first year of life.<sup>9,11</sup> MRI may demonstrate meningeal enhancement in suspected cases.<sup>5</sup> Encephalitis and ventriculitis could also be appreciated by MRI. CT is inferior to MRI for revealing any meningeal enhancement, yet it may help detect complications such as hydrocephalus, cerebral abscess, and subdural empyema (Figure 9).

### Genitourinary System

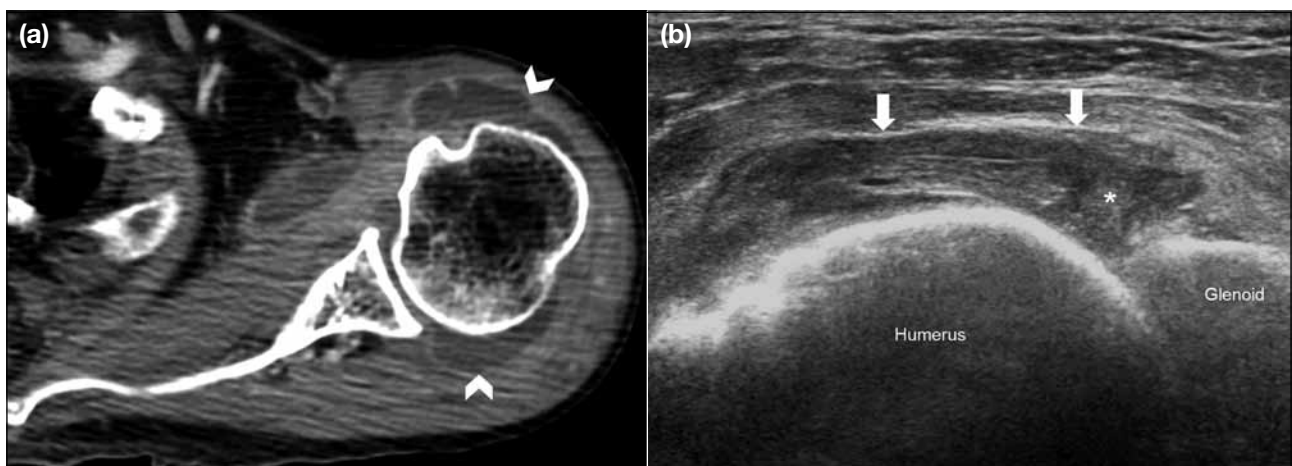
*Salmonella* urinary tract infections are uncommon. Upper urinary tract infections, particularly pyelonephritis and pyelitis, account for most of these infections.<sup>9</sup> Renal abscesses have also been reported.<sup>5</sup> Underlying structural abnormalities or immune compromise should be checked. *Salmonella* genital infections — including testicular and ovarian abscesses and, less commonly, epididymitis, prostatitis, infected hydrocele, salpingitis, and septic abortion — are rare.<sup>9</sup>

### CONCLUSION

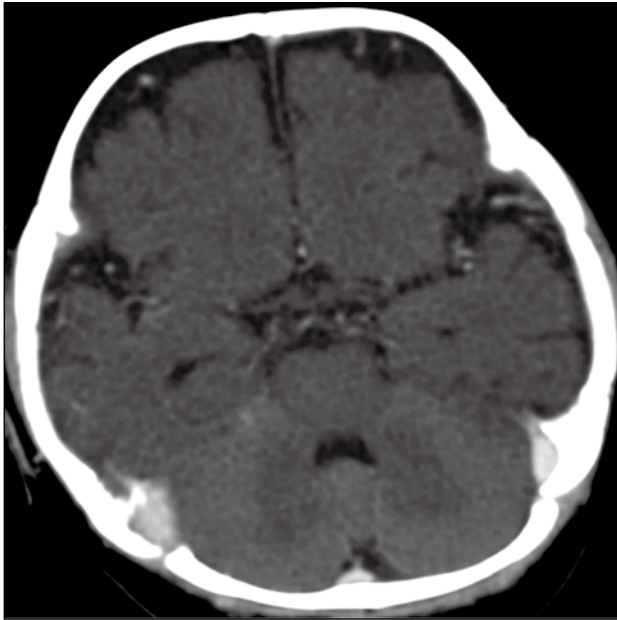
In a complicated or fulminant course of *Salmonella* infection, the key to successful treatment lies in early



**Figure 7.** Magnetic resonance, computed tomography and bone scan images of a 79-year-old man with *Salmonella* septicaemia with T7-T9 spondylodiscitis and local myelitis. (a) A sagittal T2-weighted magnetic resonance image (repetition time 3452 ms/echo time 120 ms) shows collapsed T8 (arrow) and high T2-weighted signal within the T7/8 and T8/9 discs. The adjacent thoracic cord shows a fusiform swelling and intramedullary T2-weighted hyperintensity compatible with local myelitis (arrowheads); (b) a sagittal post-gadolinium T1-weighted with fat saturation image (repetition time 533 ms/echo time 8 ms) shows marked enhancement in the T7 and T9 vertebra and epidural space (hollow arrow); and (c) a bone scan using <sup>99m</sup>Tc methylene diphosphonate shows intense horizontal uptake at T7 to T9 (curved arrow).



**Figure 8.** Computed tomography and ultrasound images of a 79-year-old man with left shoulder septic arthritis, whose joint aspirate culture yielded *Salmonella typhimurium*. He was taking immunosuppressants for idiopathic thrombocytopenic purpura. (a) Post-contrast axial computed tomography shows joint effusion with synovial thickening and enhancement (arrowheads), but no osteomyelitis; and (b) a transverse ultrasound scan of the posterior aspect of the left glenohumeral joint shows joint effusion with echogenic debris (\*) and thickening of the synovium (arrows).



**Figure 9.** A post-contrast computed tomography image of the brain of a 3-month-old infant with infantile *Salmonella* meningitis, whose blood and cerebrospinal fluid cultures grew *Salmonella* group B. The image shows no abnormal meningeal enhancement or intracranial abscess collection, and no hydrocephalus or subdural collection.

radiological diagnosis of the resultant complications. Familiarisation with the imaging spectrum by radiologists may facilitate timely antibiotic or surgical intervention. Imaging also aids monitoring of post-treatment progress and detects complications, and thus helps to minimise morbidity and mortality. All the

imaging characteristics, while obvious, are not specific for *Salmonella* infection alone, but merely show the broad spectrum of non-specific presentations of infectious diseases.

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