Emphysematous Osteomyelitis of the Spine: A Case Report and Literature Review

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Abstract:
Emphysematous osteomyelitis is a rare but potentially fatal infection. It is caused by gas-forming organisms and is characterized by the presence of intraosseous gas. A 75-year-old woman with untreated diabetes mellitus presented with difficulty in moving and anorexia. Laboratory studies revealed inflammation, a urinary infection, and diabetic ketoacidosis. *Klebsiella pneumoniae* was detected in both urine and blood cultures. Computed tomography and magnetic resonance imaging revealed emphysematous lesions in the paravertebral soft tissue, spinal canal, and iliopsoas muscle, with intraosseous gas at L1 and L2. These findings led to a diagnosis of emphysematous osteomyelitis. We herein review 35 reported cases of emphysematous osteomyelitis including our case.

Key words: diabetes mellitus, emphysematous osteomyelitis, gas-forming organisms, intraosseous gas, *Klebsiella pneumoniae*, review of the literature

(Intern Med 57: 2081-2087, 2018)
(DOI: 10.2169/internalmedicine.0219-17)

Introduction

Emphysematous osteomyelitis is a rare but serious condition that may also be fatal. The presence of intraosseous gas is generally reported after trauma, biopsy, penetrating wounds, and fractures (1). However, the formation of intraosseous gas in the extra-axial skeleton in the absence of the above conditions is suggestive of emphysematous osteomyelitis, especially in patients with infections due to gas-producing organisms (2, 3). Ram et al. first described intraosseous gas as a sign of emphysematous osteomyelitis in 1981, and to date, only 34 emphysematous osteomyelitis cases have been reported in the English literature (1-27). We herein describe the case of a 75-year-old woman with diabetes mellitus who presented with combined diabetic ketoacidosis and emphysematous osteomyelitis caused by *Klebsiella pneumoniae* due to the hematogenous spread of a urinary tract infection. In addition, we reviewed all the pertinent literature on emphysematous osteomyelitis and summarized the characteristics.

Case Report

A 75-year-old Japanese woman presented to the emergency department with a 5-day history of difficulty in moving and anorexia. She had no remarkable medical or family history, and was not taking any medication because she had never visited a medical facility. However, she had developed polydipsia and polyuria for the past 1 year. Her eyesight had worsened 2 months previously and she had simultaneously developed difficulty in walking, although she denied experiencing any trauma or pain.

On arrival, the patient was slightly drowsy, but her Glasgow Coma Score was 15 and body mass index was 25.1 kg/m². Physical examination revealed percussion pain in the vertebrae and dryness in the tongue and armpits, but no tenderness on her back, with stable vital signs (blood pressure=107/75 mmHg; pulse=95/min; body temperature=35.8°C; respiratory rate=18/min; oxygen saturation=100%). Laboratory studies indicated pyuria on urinalysis, leukocytosis (white blood cell count=21,500/μL), an increased level of C-reactive protein (22.20 mg/dL), hyperglycemia (glucose=800 mg/dL), and an increased level of glycated hemoglobin...
the same sensitivity. We did not perform a string test; there-
tures were positive for fever and thereafter became comatose. Urine and blood cul-
toacidosis, which was associated with diabetes mellitus and diabetic ke-
a urinary infection due to neurogenic bladder dysfunction.

Other laboratory tests demonstrated ketones in the urine and serum, an effective plasma osmolality of 316 mOsm/kg, an arterial pH of 7.239, a serum bicarbonate level of 14.9 mEq/L, and an anion gap of 30.1 mEq/L (Table 1). We diagnosed a urinary infection due to neurogenic bladder dysfunction which was associated with diabetes mellitus and diabetic ketoacidosis.

Shortly after hospital admission, the patient developed a fever and thereafter became comatose. Urine and blood cultures were positive for *K. pneumoniae*, which both showed the same sensitivity. We did not perform a string test; there-

fore, we could not determine whether *K. pneumoniae* was hypervirulent. Head computed tomography (CT) revealed no bleeding, masses, or edema. A plain CT of the abdomen revealed emphysematous lesions in the paravertebral soft tissue, spinal canal, and iliopsoas muscle without abscess or fracture from Th12 to L2. In addition, the presence of intra-

Figure 1. Computed tomography image of the abdomen showing emphysematous lesions around the spine (red arrows) as well as the presence of intrasosseous air (blue arrows).

(15.0%), which indicated uncontrolled diabetes mellitus. Other laboratory tests demonstrated ketones in the urine and serum, an effective plasma osmolality of 316 mOsm/kg, an arterial pH of 7.239, a serum bicarbonate level of 14.9 mEq/L, and an anion gap of 30.1 mEq/L (Table 1). We diagnosed a urinary infection due to neurogenic bladder dysfunction which was associated with diabetes mellitus and diabetic ketoacidosis.

Shortly after hospital admission, the patient developed a fever and thereafter became comatose. Urine and blood cultures were positive for *K. pneumoniae*, which both showed the same sensitivity. We did not perform a string test; there-

Figure 2. Computed tomography image of the abdomen showing emphysematous lesions around the spine (red arrows) as well as the presence of intrasosseous gas (blue arrows).
Discussion

Emphysematous osteomyelitis should be considered as one of the possible diagnoses if intraosseous gas is detected, especially in the extra-axial skeleton (22). The differential diagnosis of intraosseous gas includes trauma, post-surgical change, lymphangiomatosis of the bone, degenerative disease, osteonecrosis, and neoplasm (19, 24). To date, there have only been 34 cases of emphysematous osteomyelitis reported in the English literature. We reviewed all 34 cases as well as our case (Table 2).

The characteristics these cases showed no sex deviation, with 17 of the 35 cases reported in women. The median age at presentation was 52 years of age among women (range 14-78 years) and 51 years of age among men (range 23-72 years). Remarkable predisposing factors were diabetes mellitus (n=12), malignant tumors (n=5), alcohol abuse (n=4), enteritis (n=3), and sickle cell anemia (n=2). No predisposing factors were observed in seven cases (Fig. 4). Diabetic ketoacidosis was a complication in the present case; to the best of our knowledge, this is the first case to report the presence of diabetic ketoacidosis as a complication. Emphysematous osteomyelitis and non-emphysematous osteomyelitis are not remarkably different in terms of their symptoms. The most common symptoms include fever and pain at the infected site. It is difficult to distinguish between emphysematous osteomyelitis and non-emphysematous osteomyelitis based on only the symptoms or physical assessment; therefore, we suggest that imaging should be performed.

To date, most reported emphysematous osteomyelitis cases including our case have been monomicrobial. Among the 35 reported cases, 24 were monomicrobial, 10 were polymicrobial, and one was an unknown infection. These infections were located in the vertebrae (n=17), pelvis (n=10), femur (n=8), tibia/fibula (n=3), and sternum (n=2) (Fig. 4). The causative organisms of emphysematous osteomyelitis are similar to those reported for other gas-forming infections, such as *Escherichia coli* (n=10), *K. pneumoniae* (n=7), *Bacteroides* spp. (n=7), and *Fusobacterium* (n=5) (Fig. 4). In contrast, the most common causative agent of vertebral osteomyelitis is *Staphylococcus aureus* (28). Therefore, when diagnosing osteomyelitis caused by gas-forming organisms, emphysematous osteomyelitis should always be considered in the differential diagnosis. Vertebral infections are most commonly observed in patients with emphysematous osteomyelitis caused by *K. pneumoniae*. The rate of *K. pneumoniae* infection increases in individuals with impaired host defenses. Diabetes was an underlying condition in 36% of the cases and malignancy in 26% of the cases in a report of 101 patients with *Klebsiella* bacteremia, which is similar to that reported among emphysematous osteomyelitis cases (29).

Luey et al. (3) reviewed the literature on approximately 25 previous emphysematous osteomyelitis cases. However,
Table 2. Patients with Emphysematous Osteomyelitis Reported in the English Literature.

| Patient | 1 | 2 | 3 | 4 | 5 |
|---------|---|---|---|---|---|
| References | 1 | 2 | 3 | 4 | 5 |
| Age | 14 | 54 | 15 | 21 | 57 |
| Sex | F | F | F | F | F |
| Predisposing factor | Diabetes mellitus | Non-SCLC, typhilitis | None | None | Diabetes mellitus, hypertension |
| Location | Left femoral neck | Left femoral neck | S1 and ilium | Left iliac crest | Right femoral head |
| Bacteriologic results | Bacteroides fragilis | Clostridium septicum | Fusobacterium necrophorum | Fusobacterium necrophorum | Fusobacterium necrophorum |
| Antibiotics treatment | ND | ND | 4 weeks IV+4 weeks oral | 16 days | ND |
| Surgical treatment | None | None | Surgery 4 times | Surgery 1 time | Surgery 2 times |
| Abscess | None | None | Epidural abscess | Liver abscess | None |
| Outcome | ND | Cure | Cure | Died day 16 | Cure |
| Follow up | None | None | 18 months | - | 9 months |

| Patient | 6 | 7 | 8 | 9 | 10 |
|---------|---|---|---|---|---|
| References | 6 | 7 | 8 | 9 | 10 |
| Age | 78 | 60 | 64 | 65 | 70 |
| Sex | F | M | F | F | M |
| Predisposing factor | None | Metastatic SCLC, alcohol abuse | Hemolytic anemia, receiving prednisone | Diabetes mellitus | Diabetes mellitus |
| Location | L5 and S1 vertebrae | Pelvis, and T5, T6, L1, L4 and L5 vertebrae | L1 vertebra | L3 vertebra | T12-L5 vertebrae |
| Bacteriologic results | Fusobacterium necrophorum | Peptococcus indolicus | Escherichia coli | Escherichia coli | Escherichia coli |
| Antibiotics treatment | 4 weeks IV+8 weeks oral | 34 days | ND | 7 days | 16 days |
| Surgical treatment | None | None | None | None | L3/4 laminectomy and drainage |
| Abscess | None | Iliopsoas abscess | None | None | Epidural abscess |
| Outcome | Cure | Died day 34 | Cure | Died day 7 | Died day 16 |
| Follow up | 24 months | None | - | - | - |

| Patient | 11 | 12 | 13 | 14 | 15 |
|---------|----|----|----|----|---|
| References | 9 | 11 | 12 | 13 | 14 |
| Age | 50 | 59 | 36 | 51 | 66 |
| Sex | M | F | F | M | M |
| Predisposing factor | Diabetes mellitus, hypertension | None | Sickle cell anemia | Non-Hodgkin lymphoma | Addison’s disease |
| Location | L2 vertebra | Pelvis and vertebrae | Bilateral distal femurs and proximal tibias | Bilateral femoral heads | T7 and T8 vertebrae |
| Bacteriologic results | Klebsiella pneumoniae | Klebsiella pneumoniae | Proteus mirabilis | Salmonella serogroup D | Mycobacterium tuberculosis |
| Antibiotics treatment | 9 days | ND | ND | ND | ND |
| Surgical treatment | None | Surgery multiple times | Multiple surgeries with eventual bilateral above knee amputations | Surgery 1 time | None |
| Abscess | Liver abscess and psoas abscess | Abscess (unknown site) | Abscess of the distal ends of the femora | Abscess in the subcutaneous tissue of both thighs | None |
| Outcome | Died day 9 | Wounds still draining 6 months later. Died 2 years later from brain hemorrhage | ND | Died day 56 | ND |
| Follow up | 24 months | None | - | None | None |

Intern Med 57: 2081-2087, 2018 DOI: 10.2169/internalmedicine.0219-17
### Table 2. Patients with Emphysematous Osteomyelitis Reported in the English Literature. (continued)

| Patient | References | Age | Sex | Predisposing factor | Location | Bacteriologic results | Antibiotics treatment | Surgical treatment | Outcome | Follow up |
|---------|------------|-----|-----|---------------------|----------|-----------------------|----------------------|-------------------|---------|-----------|
| 16      | 17         | 18  | 19  | 20                  | L3 and L4 vertebrae | Escherichia coli, Klebsiella spp, Streptococcus Group D | Streptococcus | None | None | -         |
| 15      | 16         | 16  | 16  | 17                  | Sacrum   | Escherichia coli, Streptococcus fragilis | Vellomella spp, Staphylococcus epidermidis, Candida spp | None | -       |
| 20      | 18         | 19  | 18  | 19                  | Sacrum   | Pelvic girdle and right femoral head | None | None | -         |

| Patient | References | Age | Sex | Predisposing factor | Location | Bacteriologic results | Antibiotics treatment | Surgical treatment | Outcome | Follow up |
|---------|------------|-----|-----|---------------------|----------|-----------------------|----------------------|-------------------|---------|-----------|
| 21      | 22         | 23  | 24  | 25                  | L3 and L4 resection and bone graft fusion | L3 and L4 | Streptococcus | Surgery 1 time | Paraspinal abscess | None | -         |
| 20      | 19         | 8   | 17  | 17                  | Sacrum   | Streptococcus | None | Drainage | Presacral abscess | None | -         |

| Patient | References | Age | Sex | Predisposing factor | Location | Bacteriologic results | Antibiotics treatment | Surgical treatment | Outcome | Follow up |
|---------|------------|-----|-----|---------------------|----------|-----------------------|----------------------|-------------------|---------|-----------|
| 23      | 49         | 58  | 37  | 51                  | Right femur | Bacteroides melaninigenicus, Propionibacterium spp, alpha-hemolytic Streptococcus | None | None | None | None | None | -         |

| Patient | References | Age | Sex | Predisposing factor | Location | Bacteriologic results | Antibiotics treatment | Surgical treatment | Outcome | Follow up |
|---------|------------|-----|-----|---------------------|----------|-----------------------|----------------------|-------------------|---------|-----------|
| 26      | 27         | 28  | 29  | 30                  | L5 vertebra | Bacteroides stercoris, Propionibacterium spp, Streptococcus milleri, Streptococcus mitis | None | None | None | None | None | -         |

| Patient | References | Age | Sex | Predisposing factor | Location | Bacteriologic results | Antibiotics treatment | Surgical treatment | Outcome | Follow up |
|---------|------------|-----|-----|---------------------|----------|-----------------------|----------------------|-------------------|---------|-----------|
| 20      | 21         | 58  | 53  | 72                  | Metatarsals remnants, midtarsal bones, and head of the talus | Klebsiella spp | Streptococcus | Right below-knee amputation | None | None | -         |

| Patient | References | Age | Sex | Predisposing factor | Location | Bacteriologic results | Antibiotics treatment | Surgical treatment | Outcome | Follow up |
|---------|------------|-----|-----|---------------------|----------|-----------------------|----------------------|-------------------|---------|-----------|
| 20      | 21         | 58  | 53  | 72                  | L2 and L3 vertebrae | Klebsiella pneumoniae | Streptococcus | None | None | -         |

| Patient | References | Age | Sex | Predisposing factor | Location | Bacteriologic results | Antibiotics treatment | Surgical treatment | Outcome | Follow up |
|---------|------------|-----|-----|---------------------|----------|-----------------------|----------------------|-------------------|---------|-----------|
| 20      | 21         | 58  | 53  | 72                  | L4 and L5 vertebrae | Escherichia coli | None | None | None | -         |

| Patient | References | Age | Sex | Predisposing factor | Location | Bacteriologic results | Antibiotics treatment | Surgical treatment | Outcome | Follow up |
|---------|------------|-----|-----|---------------------|----------|-----------------------|----------------------|-------------------|---------|-----------|
| 20      | 21         | 58  | 53  | 72                  | Pelvis and vertebrae | None | None | None | None | -         |
Table 2. Patients with Emphysematous Osteomyelitis Reported in the English Literature. (continued)

| Patient | References | Age | Sex | Predisposing factor | Location | Bacteriologic results | Antibiotics treatment | Surgical treatment | Abscess | Outcome | Follow up |
|---------|------------|-----|-----|---------------------|----------|-----------------------|----------------------|-------------------|---------|---------|----------|
| 31      | 24         | 46  | M   | Alcohol abuse       | Lumbar vertebrae | Klebsiella pneumoniae | 2 days               | Debridement 1 time | None    | Died day 2 | -        |
| 32      | 25         | 62  | M   | Arthroscopy of the knee | Sacrum | Fusobacterium necrophorum | 16 days              | None              | Piniformis muscle abscess | Died day 16 | -        |
| 33      | 26         | 74  | F   | Multiple myeloma    | Sternum and T6 vertebrae | Esherichia coli | 20 days | None | None | Died day 10 |
| 34      | 27         |      | F   | Diabetes mellitus, hypertension | Sternum and left clavicle | Esherichia coli | 13 weeks IV | Debridement 1 time | None | -        |
| 35      | This case  |      |     | Diabetes mellitus   | L1 and L2 vertebrae | Klebsiella pneumoniae | 10 days |       |       |          |

**Bacteriologic results**

- **E. Coli**: 14%
- **Klebsiella pneumoniae**: 30%
- **Bacteroides spp**: 8%
- **Fusobacterium necrophorum**: 6%

**Location**

- Vertebral area: 4%
- Pelvis: 10%
- Femur: 25%
- Tibia/Fibula: 39%
- Sternum: 16%

**Predisposing Factor**

- Diabetes mellitus: 12%
- Malignant tumor: 10%
- Alcohol abuse: 11%
- Enteritis: 6%
- Sickle cell anemia: 5%
- None: 20%

cause bacteremic dissemination, including endophthalmitis, meningitis, and necrotizing fasciitis. The invasive nature of some *K. pneumoniae* strains includes a hypermucoviscous phenotype associated with serotypes K1 and K2 and a regulator of the mucoid phenotype A gene. Definite invasive syndrome is defined as a *K. pneumoniae* infection caused by the K1 or K2 serotype. Furthermore, invasive syndrome is defined as the hypermucoviscous phenotype confirmed by a string test, which monitors the formation of a viscous string >0.5 cm in length which is stretched by the inoculation loop. We assume that this invasive syndrome includes emphysematous osteomyelitis. We did not test for this phenotype in our case; however, an invasive *K. pneumoniae* infection may occur. Further studies are needed to evaluate the emphysematous osteomyelitis caused by *Klebsiella* species.

Empiric treatment should include antibiotics with activities against the causal microbe. Unfortunately, the details regarding the optimal duration for administering antibiotics for the treatment of emphysematous osteomyelitis cases has not been elucidated in the pertinent literature, and thus no definitive conclusions can be made. However, the high level of surgical intervention and high mortality rate associated with emphysematous osteomyelitis are clearly evident (17). Surgical intervention should be considered for the treatment of acute osteomyelitis if abscess formation or radiologic evidence of necrosis is detected (26). Among the reported 35 cases, at least 19 cases (54%) required surgical intervention and four cases (11%) required multiple surgeries. There were 19 cases with abscesses. Our case did not have any abscess; therefore, no surgery was required. However, surgery was performed in three cases without any abscess for infectious source control, which led to a good prognosis. In contrast, surgery performed in three cases with abscesses resulted in a fatal outcome. Compared with vertebral osteomyelitis, with a mortality rate of 6% to 11%, emphysematous osteomyelitis was associated with a higher mortality rate (37%; 13 patients emphysematous osteomyelitis died in the hospital 56 days after diagnosis) (30-32).

Therefore, our findings suggest that an early diagnosis...
and immediate treatment, including effective antibiotics and surgical intervention, when indicated, are essential for preventing the potentially fatal consequences associated with emphysematous osteomyelitis.

The authors state that they have no Conflict of Interest (COI).

References

1. Kumar J, Bandhu S, Resnick D, Kumar A. Intraosseous and intraarticular pneumonia in anaerobic osteomyelitis. Pediatr Radion 36: 1220, 2006.
2. Kühiczak D, Epstein R. Clostridium septicum osteomyelitis with intramedullary gas on CT and MR imaging. AJR Am J Roentgenol 172: 1457-1458, 1999.
3. Levy C, Tooey D, Briggs D. Emphysematous osteomyelitis: a case report and review of the literature. Int J Infectious Dis 16: 216-220, 2012.
4. Vohra A, Saiz E, Ratzan KR. A young woman with a sore throat, septicemia, and respiratory failure. Lancet 350: 928, 1997.
5. Foulkes GD, Johnson CE, Katner HP. Fusobacterium osteomyelitis associated with intraosseous gas. Clin Orthop Relat Res 251: 246-248, 1990.
6. Le Moal G, Juhel L, Grollier G, Godet C, Azais I, Roblot F. Intraosseous gas formation due to Fusobacterium species: report of three cases and review of the literature. J Infect 51: E5-E9, 2005.
7. Philippe J, Sheybani E, Hirschel B, Ody B. Air in the bones: multifocal anaerobic osteomyelitis associated with oat cell carcinoma. Br Med J (Clin Res Ed) 290: 969, 1985.
8. Bielecki DK, Sartoris D, Resnick D, VanLom K, Fierer J, Haghigi P. Intraosseous and intradiscal gas in association with spinal infection: report of three cases. AJR Am J Roentgenol 147: 83-86, 1986.
9. Chen CW, Yang CJ, Huang JJ, Chuang YC, Young C. Gas-forming vertebral osteomyelitis in diabetic patients. Scand J Infect Dis 23: 263-265, 1991.
10. Al-Wakeel J, Al-Ballaa SR, Sergani H, Abu-Aisha H, Huraib S, Mitwalli A. Non-clotridial gas-forming infections in diabetic patients. Ann Saudi Med 15: 71-73, 1995.
11. Lew DP, Waldvogel FA. Osteomyelitis. Lancet 364: 369-379, 2004.
12. Marx AC, Hartshorne MF, Stull MA, Truwit CL. Case report 496: intraosseous gas in Proteus mirabilis osteomyelitis complicating bone infarcts in sickle cell disease. Skeletal Radiol 17: 510-513, 1988.
13. Putcharoen O, Suankratay C. Salmonella gas-forming femoral osteomyelitis and pyomyositis: the first case and review of the literature. J Med Assoc Thai 90: 1943-1947, 2007.
14. Lardé D, Mathieu D, Frijia J, Gaston A, Vasile N. Spinal vacuum phenomenon: CT diagnosis and significance. J Comput Assist Tomogr 6: 671-676, 1982.
15. Charles RW, Mody GM, Govender S. Pyogenic infection of the lumbar vertebral spine due to gas-forming organisms. Spine (Phila Pa 1976) 14: 541-543, 1989.
16. Merine D, Fishman EK, Magid D. CT detection of sacral osteomyelitis associated with pelvic abscesses. J Comput Assist Tomogr 12: 118-121, 1988.
17. Ram PC, Martinez S, Korobkin M, Breiman RS, Gallis HR, Harrelson JM. CT detection of intraosseous gas: a new sign of osteomyelitis. AJR Am J Roentgenol 137: 721-723, 1981.
18. Patton HM, Conlan JK, Long RF, Waller JT. Unusual presentation of anaerobic osteomyelitis. Am J Med 75: 724-726, 1983.
19. Potocki J, Kaushik S, Mira JL. Anaerobic osteomyelitis of femoral head with intraosseous, intra-articular, bursal and muscle pneumatosis. Skeletal Radiol 32: 46-48, 2003.
20. McDonnell O, Khaelez Z. Emphysematous osteomyelitis. JAMA Neurrol 71: 512, 2014.
21. Mautone M, Gray J, Naidoo P. A case of emphysematous osteomyelitis of the midfoot: imaging findings and review of the literature. Case Rep Radiol 2016: e16184, 2014.
22. Aiyappan SK, Ranga U, Veevraiyan S. Spontaneous emphysematous osteomyelitis of spine detected by computed tomography: report of two cases. J Craniomervectorjunction Spine 5: 90-92, 2014.
23. Larsen J, Mühlbauer J, Wigger T, Bardosi A. Emphysematous osteomyelitis. Lancet Infect Dis 15: 486, 2015.
24. Chen JL, Huang YS. Emphysematous osteomyelitis of spine. QJM 109: 427-428, 2016.
25. Velickovic M, Hockertz T. Sacral emphysematous osteomyelitis caused by Escherichia coli after arthroscopy of the knee. Case Rep Orthop 2016: 1961287, 2016.
26. Park SS, Lee SE, Min CK. Emphysematous osteomyelitis due to Escherichia coli in multiple myeloma. Blood Res 51: 224, 2016.
27. Lee J, Jeong CH, Lee MH, et al. Emphysematous osteomyelitis due to Escherichia coli. Infect Chemother 49: 151-154, 2017.
28. Siu LK, Yeh KM, Lin JC, Fung CP, Chang FY. Klebsiella pneumonia liver abscess: a new invasive syndrome. Lancet Infect Dis 12: 881-887, 2012.
29. Lee KH, Hui KP, Tan WC, Lim TK. Klebsiella bacteremia: a report of 101 cases from National University Hospital, Singapore. J Hosp Infect 27: 299-305, 1994.
30. Lew DP, Waldvogel FA. Osteomyelitis. Lancet 364: 369-379, 2004.
31. McHenry MC, Easley KA, Locker GA. Vertebral osteomyelitis: long-term outcome for 253 patients from 7 Cleveland-area hospitals. Clin Infect Dis 34: 1342-1350, 2002.
32. Akiyama T, Chikuda H, Yasunaga H, Horiguchi H, Fushimi K, Saita K. Incidence and risk factors for mortality of vertebral osteomyelitis: a retrospective analysis using the Japanese diagnosis procedure combination database. BMJ Open 3: e002412, 2013.