Salmonella enterica subspecies arizonae infection of adult patients in Southern Taiwan: a case series in a non-endemic area and literature review

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Background
Salmonellae are Gram-negative, non-spore-forming, facultatively anaerobic bacilli belonging to the family of Enterobacteriaceae, which usually cause food-borne diseases. Salmonella arizonae, one of the less common members of Salmonellae, has the distinguishing biochemical characteristics of the ability to ferment lactose, utilize malonate, liquefy gelatin, and inhibition by the presence of potassium cyanide [1]. It was first reported in diseased reptiles in 1939 by Caldwell and Ryerson, and was named Salmonella dar-es-salaam at that time [2]. It has also been subsequently named Arizona hinshawii, S. arizonae, S. cholerasuis subsp. arizonae and finally reclassified as S. enterica subsp. arizonae in 1983 (S. arizonae was used throughout this manuscript) [3].

It was initially considered to be pathogenic only in reptiles, especially in snakes, with as many as 78.8% of them harboring the organism [4]. It was occasionally responsible for severe outbreaks in turkeys and sheep [4]. The first case of human infection by S. arizonae, presented with gastroenteritis, was recognized in 1944 [5]. Thereafter, S. arizonae was noted to be able to cause a...
spectrum of human diseases, including gastroenteritis, bacteraemia, vascular infection, bone and joint infection, and central nervous system infection [1, 4, 6–22]. Most of these infections have a good prognosis without any complications. However, severe human infection caused by *S. arizonae* has been documented in children below 7 years of age [23], immunocompromised adults, (e.g., autoimmune diseases under steroid therapy [1, 8, 10, 11, 14, 24, 25], malignancy [7, 13, 14, 21, 26–29], human immunodeficiency virus (HIV) infection [1, 15, 17, 19, 30, 31], organ transplantation [11, 32]), or even in immunocompetent populations [18]. Cold-blooded animals are the usual habitats of *S. arizonae*, especially in reptiles or rattlesnake-based products. Other animals, including poultry, rats, and dogs [6, 9, 17], have also been involved in human infection by *S. arizonae*. According to previously published articles [1, 10, 13, 14, 16, 25–29, 31], the geographic distributions of *S. arizonae* human infections are mainly located in south-western United States, where the use of rattlesnake-associated products to treat a wide variety of illnesses is popular among Mexican-Americans populations. Around 20 pediatric patients below 18 years of age suffering from *S. arizonae* infection have been reported in the literature [9, 17, 21, 23]. Little is known about *S. arizonae* infection of adult patients in Asian countries, including Taiwan. The aim of this study was to analyze all adult patients with *S. arizonae* infection at a regional teaching hospital in southern Taiwan and to perform a literature review on similar patients.

**Methods**

From July 2007 to June 2014, all adult patients (≥18 years) diagnosed with *S. arizonae* infection and treated for at least 3 days at Chia-Yi Christian Hospital (CYCH, a regional teaching hospital with a capacity of 1000 beds in southern Taiwan) were retrospectively enrolled. *S. arizonae* infection was defined as positive cultures of any kind of clinical specimens, including blood, pleural effusion, ascites, urine, sputum, stool, pus and bone, for *S. arizonae* plus the presence of signs of systemic or local infection. All types of specimens were collected, transported, and processed according to the suggestion described previously [33], and then inoculated into the corresponding culture media for subsequent incubation [34]. The blood culture system at CYCH was Bactec FX system (Becton, Dickinson and Co. [BD], Franklin Lakes, NJ). All bone tissues were collected by bone biopsy or surgical procedures. Potential pathogens were identified by Vitek version 2.0 (bio Merieux Suisse S.A., Geneva, Switzerland), and *Salmonella* isolates were confirmed by serologic testing (Difco™ Antiserum Solutions). The culture-positive cases were identified by reviewing microbiology records at CYCH. A standardized case report form was used to collect the demographics, clinical and laboratory data and treatment outcomes. Patients who used H$_2$-receptor antagonists or proton pump inhibitors within one month prior to admission were defined as having peptic ulcer disease. Leukocytosis was defined as white blood cell counts exceeding 10 K/μl and thrombocytopenia was defined as platelet count below 150 K/μl. The infection foci of non-bacteraemic patients and patients with secondary bacteraemia were determined if there was a presence of clinical symptoms or signs of infection and isolation of *S. arizonae* from related clinical specimens. Bacteraemia without an obvious infection source or related to intravascular catheter infection or vascular lesions was classified as primary bacteraemia.

The antimicrobial susceptibilities to chloramphenicol, ciprofloxacin, trimethoprim/sulfamethoxazole, ampicillin and ceftiraxone were determined using the disk diffusion method according to the recommendation of the Clinical and Laboratory Standards Institute (CLSI) [35]. The results were also interpreted using the criteria suggested by CLSI [36]. Antimicrobial agents given before the susceptibility results were defined as empirical therapy, whereas definitive therapy was defined as effective antibiotic therapy prescribed according to the results of final blood cultures and susceptibility testing. The study was approved by the ethics review boards of the hospital [Chia-Yi Christian Hospital-Institutional Review Board (CYCH-IRB) No. 104035, 06/30/2015]. The IRB waived informed consent due to the retrospective study design and the research posing no more than minimal risk.

Continuous variables were described as medians with interquartile ranges (IQR) and categorical variables were described as percentage.

**Results**

A total of 485 adult patients with *Salmonella* species infection were identified during this seven-year period, and only 4.7% (23/485) of those patients suffered from *S. arizonae* infection. Five among them were excluded because they received treatment for less than 3 days at CYCH and did not follow-up subsequently. For the five eliminated patients, the median age was 65 years (IQR, 60–72 years). Four of them had primary bacteraemia and one had pneumonia. The demographics, clinical features, laboratory data and treatment outcome of the enrolled 18 patients are showed in Table 1. Of these 18 patients, the median age was 63.5 years, ranging from 27 to 81 years, with 12 men and six women. All patients lived in Chiayi City, except one, who lived in Yunlin County. All patients had various underlying diseases, including endocrine diseases in 12 (66.7%; diabetes mellitus in ten, and another diseases in two), peptic ulcer disease in eight (44.4%), malignancy in eight (34.8%; hepatocellular
carcinoma in four, lung cancer in three, and colon cancer in one), hypertension in seven (38.9%), liver cirrhosis in six (33.3%), chronic viral hepatitis in six (33.3%; hepatitis B virus in five, and hepatitis C virus in two), chronic kidney disease in three (16.7%), autoimmune diseases in one, and acquired immunodeficiency syndrome in one (5.6%).

Nine patients (50.0%) had fever as their first presentation. The other initial presentations included abdominal discomfort (7/18, 38.9%), dyspnoea (7/18, 38.9%), cough (3/18, 16.7%), diarrhea (3/18, 16.7%), change in consciousness (2/18, 11.1%), and arthralgia (2/18, 11.1%).

The median initial body temperature was 37.2 °C (IQR, 36.1–38.3) and 14 patients (77.8%) had initial heart rates above 90 beats per minute. Hypotension (systolic blood pressure < 90 mmHg) occurred in three patients. Leucocytosis was noted in ten patients (55.6%), and nine (50.0%) patients had thrombocytopenia. Seventeen patients had neutrophilia and eight patients (47.1%, one missing data) had elevated C-reactive protein levels of up to more than 10 mg/dL. For liver function tests, 11 patients (64.7%) had elevated aspartate or alanine transaminase values (AST > 38 U/L or ALT > 44 U/L). Impaired renal function at presentation, defined as serum creatinine > 1.3 mg/dl, was noted in 41.2% (7/17) of patients. Leucocytosis was noted in ten patients (55.6%), and nine (50.0%) patients had thrombocytopenia. Seventeen patients had neutrophilia and eight patients (47.1%, one missing data) had elevated C-reactive protein levels of up to more than 10 mg/dL. For liver function tests, 11 patients (64.7%) had elevated aspartate or alanine transaminase values (AST > 38 U/L or ALT > 44 U/L). Impaired renal function at presentation, defined as serum creatinine > 1.3 mg/dl, was noted in 41.2% (7/17, one missing data) of patients. Initial serum albumin level was available in 13 patients only and 11 of them (84.6%) had hypoalbuminemia (albumin < 3 g/dL). Hyponatremia (sodium < 135 mmol/L) was found in 82.4% of patients (14/17, one missing data), and only four patients (23.5%, one missing data) had hypokalaemia (potassium < 3.5 mmol/L). Serum glucose level at presentation was only available in 13 patients, and five (38.5%) of them had elevated levels of ≥ 200 mg/dL.

Blood cultures were obtained in all 18 patients, and bacteraemia was identified in ten (55.6%), including primary bacteraemia in two, both with mycotic aneurysm and secondary bacteraemia in eight. The most common infection foci of patients with secondary bacteraemia and non-bacteraemic clinical syndromes were lower respiratory

| Table 1 Demographics and clinical data of 18 patients with *S. arizonae* infections in our case series |
|-----------------------------------------------|
| Age by years (median, range)                  | 63.5 (27–81) |
| Male to female ratio                          | 12 : 6       |
| Underlying diseases (No., %)                  |              |
| Diabetes mellitus                             | 10 (55.6)    |
| Hypothyroidism                                | 2 (11.1)     |
| Peptic ulcer diseases                         | 8 (44.4)     |
| Hepatocellular carcinoma                      | 4 (22.2)     |
| Lung cancer                                   | 3 (16.7)     |
| Colon cancer                                  | 1 (5.6)      |
| Multiple myeloma                              | 1 (5.6)      |
| Hypertension                                  | 7 (38.9)     |
| Liver cirrhosis                               | 6 (33.3)     |
| Hepatitis B                                   | 5 (27.8)     |
| Hepatitis C                                   | 2 (11.1)     |
| Chronic kidney diseases                       | 3 (16.7)     |
| Systemic lupus erythematosus                  | 1 (5.6)      |
| AIDS                                          | 1 (5.6)      |
| Symptoms (No., %)                             |              |
| Fever                                         | 9 (50.0)     |
| Abdominal discomfort                          | 7 (38.9)     |
| Dyspnea                                       | 7 (38.9)     |
| Laboratory data (No., %)                      |              |
| WBC > 10000/μl                                | 10 (55.6)    |
| CRP > 10 mg/dL                                | 8/17 (47.1)  |
| ALT > 44 U/L                                  | 8/17 (47.1)  |
| Creatinine > 1.3 mg/dl                        | 7/17 (41.2)  |
| Site of bacterial isolation (No., %)           |              |
| Blood                                         | 10 (55.6)    |
| Bone                                          | 2 (11.1)     |
| Abscess                                       | 2 (11.1)     |
| Pleural effusion                              | 2 (11.1)     |
| Sputum                                        | 1 (5.6)      |
| Stool                                         | 1 (5.6)      |
| Ascent                                        | 1 (5.6)      |
| Urine                                         | 1 (5.6)      |
| Clinical presentations (No., %)                |              |
| Lower respiratory tract infection              | 4 (22.2)     |
| Bone and joint infection                      | 3 (16.7)     |
| Gastrointestinal tract infection               | 3 (16.7)     |
| Intra-abdominal infection/peritonitis          | 3 (16.7)     |
| Soft tissue infection                         | 2 (11.1)     |
| Mycotic aneurysm                              | 2 (11.1)     |
| Urinary tract infection                       | 1 (5.6)      |
| Definite antibiotic treatment (No., %)         |              |
| 3rd generation cephalosporins                 | 13 (72.2)    |
| Fluoroquinolones                              | 3 (16.7)     |
| Piperacillin/tazobactam                       | 1 (5.6)      |
| TMP/SMX                                       | 1 (5.6)      |
| Intensive care unit stay (No., %)              | 9 (50.0)     |
| Length of hospitalization, days (mean ± standard deviation) | 19.7 ± 13.7 |
| In-hospital mortality (No., %)                 | 1 (5.6)      |

*AIDS acquired immunodeficiency syndrome, WBC white blood cell, CRP C-reactive protein, ALT alanine aminotransferase, TMP/SM trimethoprim/sulfamethoxazole*
tract (4/18, 22.2%), followed by bone and joint (n = 3, 16.7%), gastrointestinal tract (n = 3, 16.7%), intra-abdominal infection or peritonitis (n = 2, 11.1%), and urinary tract (n = 1, 5.6%). In-vitro susceptibility testing revealed that all isolates were susceptible to all of the five tested antimicrobials, i.e. no strains had decreased susceptibility to ciprofloxacin according to the 2013 CLSI guidelines. Seven patients received effective empirical antibiotics. The definite therapy included third-generation cephalosporins in 13 (72.2%) of 18 patients, of which three patients received combined therapy (oral co-trimoxazole in two and ciprofloxacin in one), fluoroquinolone in three (16.7%), piperacillin/tazobactam in one (5.6%), and oral co-trimoxazole in one (5.6%). The median duration of treatment was 12 days, ranging from 5 to 62 days. Of the 18 patients, the median hospital stay was 14 days, ranging from 6 to 62 days. Nine (50.0%) patients were admitted to the intensive care unit during their hospitalization. 17 patients recovered from this infection successfully after completion of the treatment course, and one patient died. Overall, the crude in-hospital mortality rate was 5.6% (1/18).

Discussion

Our present study demonstrates that S. arizonae infection is uncommon among adult patients with a crude in-hospital mortality rate of 5.6%. To the best of our knowledge, this is the largest case series reporting adult patients infected by S. arizonae. Based on a thorough search in PubMed, there were 27 studies reporting and discussing patients with S. arizonae infection from 1959 to the writing of the present manuscript. Clinical characteristics of these 44 reported patients, including age, gender, underlying diseases, type of infection, antibiotic therapy, exposure and treatment outcome, are displayed in Table 2. Patients in the present study were either elderly male or had various underlying conditions (Table 1) which would compromise their cell-mediated immunity. In the literature (Table 2), the most commonly reported comorbidities associated with S. arizonae infections were immunocompromised status, including connective tissue diseases under steroid therapy (40.9%), malignancy (27.3%) and acquired immunodeficiency syndrome (13.6%) [15, 17]. Our case series produced similar findings. Additionally, we identified three more associated host underlying conditions, including type 2 diabetes mellitus, liver cirrhosis, and peptic ulcer disease. Uncontrolled diabetes and liver cirrhosis have been shown to cause impairment of humoral- and cell-mediated immunity, which play important roles in clearing Salmonella [37]. Therefore, these two diseases would reasonably predispose to the development of S. arizonae infection. Moreover, patients with peptic ulcer diseases received acid suppressants to treat their diseases. Usage of acid suppressants would not only decrease the acidity of gastric juice, which in turn might result in intestinal bacterial overgrowth, facilitate bacterial translocation from the intestine and lead to infection via the gastro-intestinal route [38], but also reduce the gastric acid barrier with subsequent infection despite a lower inoculum of bacteria. Similar findings have been previously reported by Wu et al. [39].

A variety of clinical manifestations were displayed in our series, including enterocolitis, bacteraemia, vascular infection and localized infections. The rank order of infection syndromes in our reports was bacteraemia, intra-abdominal infection, and pulmonary infection. In contrast, bacteraemia [1, 7, 10, 13–15, 17–19, 21, 22, 26, 28, 30–32], intra-abdominal infection [4, 6, 10–12, 14, 17, 21, 24, 27, 29, 30, 32, 40] and bone or joint infection [8, 9, 11, 12, 14, 20, 21, 24] were the most common clinical manifestations in previously-reported patients (Table 2). Much fewer patients with bone and joint infection (16.7%) were noted in our present study. Interestingly, both of the two patients in our series diagnosed as S. arizonae related mycotic aneurysm had a past history of hypertension. This is similar to the result by Wang JY et al., who demonstrated that hypertension was the major factor predisposing to S. cholerae-suis mycotic aneurysm [41]. Importantly, our study is the first one to demonstrate that soft tissue could be the infection focus of S. arizonae, which was observed in two of our patients. Overall, the difference in clinical manifestations between our study and prior reports might be due to the small number of patients enrolled in every study. Therefore, further study is needed to clarify whether geographic variance or other factors were associated with the difference of clinical syndromes.

All S. arizonae isolates collected in the present study were susceptible to all five of the recommended antimicrobials, including chloramphenicol, ciprofloxacin, trimethoprim/sulfamethoxazole, ampicillin, and ceftriaxone. These five antimicrobial agents have the ability to penetrate host cells, which is crucial in killing intra-cellular pathogens, such as Salmonella. All of our patients received at least one of these five agents as their definite therapy, among which third-generation cephalosporins were prescribed for the majority of patients (72.2%, Table 1). Instead, ampicillin was usually chosen as the backbone of the treatment modality (45.2%) in previously published articles (Table 2). Although the difference was not statistically significant (p = 0.1 by chi-square test), the crude in-hospital mortality rate was only 5.6% in the present study, which was much lower than that (10/44, 22.7%) of the prior reports (Table 2). In particular, 6 of the 10 fatal patients in prior reports received ampicillin as their treatment against S. arizonae infection. Therefore, a third-generation cephalosporin could potentially be a better choice for treating S. arizonae
| Reference       | Age | Gender | Underlying Diseases            | Type of Infection                     | Antibiotic Treatment       | Exposure | Outcome |
|-----------------|-----|--------|--------------------------------|--------------------------------------|----------------------------|----------|---------|
| Krag 1959 [20]  | 63  | F      | idiopathic thrombocytopenic purpura | knee septic arthritis               | achromycin                 | unknown  | death   |
| Guckian 1967 [24] | 52  | F      | SLE, DM                         | knee septic arthritis/gastroenteritis/UTI | cephalothin/amoxicillin/chloramphenicol | unknown  | recover |
| Andrews 1970 [6] | 21  | M      | none                            | gastroenteritis                      | ampicillin/chloramphenicol | dog      | recover |
| Smilack 1975 [8] | 23  | F      | SLE                             | knee/shoulder arthritis/tibial abscess | ampicillin/cefhalothin     | unknown  | recover |
| Arora 1976 [18] | 30  | M      | none                            | gastroenteritis                      | chloramphenicol            | unknown  | recover |
| Keren 1976 [12] | 53  | M      | alcoholism                       | osteomyelitis/gastroenteritis        | ampicillin/aminoglycoside  | unknown  | recover |
| Johnson 1976 [32] | 29  | M      | Hodgkin's disease               | bacteraemia/gastroenteritis/UTI      | cephalothin/gentamicin     | unknown  | death   |
| Johnson 1976 [32] | 54  | M      | post heart transplant           | bacteraemia/gastroenteritis          | cephalothin/gentamicin     | unknown  | death   |
| Johnson 1976 [32] | 54  | F      | mental retardation              | gastroenteritis/pneumonia/empyema    | ampicillin                | unknown  | recover |
| Petru 1981 [22] | 53  | M      | DM/interstitial pneumonitis      | bacteraemia/mycotic aneurysm         | ampicillin/gentamicin      | NA       | recover |
| Lindsay 1981 [40] | 69  | F      | cirrhosis                       | bacteraemia/peritonitis              | cephalosporin/aminoglycoside/chloramphenicol | unknown  | death   |
| Fainstein 1982 [13] | 66  | M      | leukaemia                       | bacteraemia                          | ticarillin/aminoglycoside  | rattlesnake capsule | death   |
| McIntyre 1982 [16] | 73  | M      | DM/HTN                          | septic arthritis/aortic aneurysm/UTI | ampicillin                | rattlesnake capsule | recover |
| CDC 1983 [7]    | 63  | F      | gallbladder adenocarcinoma       | bacteraemia                          | ?                         | Rattlesnake capsule | recover |
| Quismorio 1983 [11] | 31  | F      | SLE                             | septic arthritis                     | ampicillin                | unknown  | death   |
| Quismorio 1983 [11] | 41  | M      | HB, post renal transplant        | septic arthritis/ kidney abscess     | ampicillin                | unknown  | death   |
| Quismorio 1983 [11] | 48  | F      | Waldenstrom macroglobulinemia   | septic arthritis/gastroenteritis/UTI | ampicillin                | unknown  | death   |
| Riley 1988 [1]  | 19  | F      | SLE                             | bacteraemia                          | ampicillin                | rattlesnake capsule | recover |
| Riley 1988 [1]  | 25  | M      | AIDS                            | adenitis/empyema                     | TMP/SMX                   | rattlesnake capsule | recover |
| Riley 1988 [1]  | 51  | M      | HTN/DCM/CHF/atrial fibrillation  | pleurisy                             | nil                       | rattlesnake capsule | recover |
| Bhatt 1989 [10] | 27  | F      | SLE                             | bacteraemia/gastroenteritis/periitonitis/meningitis | ampicillin | rattlesnake meat | death   |
| Fleischman 1989 [28] | 38  | M      | gastric carcinoma               | bacteraemia/empyema                  | ampicillin                | rattlesnake capsule | recover |
| Jacobson 1989 [19] | 49  | F      | AIDS                            | bacteraemia                          | ciprofloxacin             | unknown  | recover |
| Cone 1990 [14]  | 71  | F      | RA                              | bacteraemia/arthritis/gastroenteritis | ceftriaxone/chloramphenicol | folk remedy | recover |
| Cone 1990 [14]  | 72  | M      | metastatic melanoma             | bacteraemia                          | aztreonam                 | rattlesnake capsule | recover |
| Casner 1990 [31] | 30  | M      | AIDS/Kaposi's sarcoma           | bacteraemia/UTI                      | Baktar                    | rattlesnake capsule | recover |
infection compared to ampicillin. However, further investigation is needed.

One patient in our study received piperacillin/tazobactam, which is not the recommended antibiotic as the definitive treatment against *Salmonella*, and had a favorable outcome. Using piperacillin/tazobactam for *Salmonella* infection was rarely reported in previous articles. Bell SD demonstrated that minimal inhibitory concentration of piperacillin/tazobactam for *S. arizonae* isolated from this study was \( \leq 4 \) μg/mL [4], implicating the bacterium susceptible to it in-vitro. Gerada et al. reported a liver transplant recipient with *Salmonella* related infectious aortitis and bacteraemia, who responded well to piperacillin/tazobactam treatment [42]. Thus, piperacillin/tazobactam might be considered as one of the therapeutic options for *S. arizonae* infection.

During the 1980s, *S. arizonae* infection became an important issue in public health due to the emergence of many severe infection cases, and its association with extensive use of rattlesnake-based products [10, 19, 28] mainly in areas with large Mexican-American populations in southwestern United States [1, 7, 13]. Approximately 70% of the 44 patients reported in previous studies (Table 2) mentioned a history of exposure to reptiles, especially snakes. Rattlesnake-based products are not common in Taiwan and we could not identify any specific animal contact history from the medical records of those patients. It is important to identify whether natural habitats of *S. arizonae* are present and whether *S. arizonae* infection is one of the zoonoses in Taiwan. Further studies are needed to identify the possible sources of this infection.

### Conclusions

Our study showed that *S. arizonae* infection, although uncommon, is present in Taiwan, an area outside of typical endemic areas. In addition to previously reported risk factors, usage of acid suppressants, such as proton pump inhibitors and H2 blockers, might also predispose to *S. arizonae* infection. To treat *S. arizonae* infection,

### Table 2
Characteristics, clinical diseases and outcome of 44 human infections with *S. arizonae* reported in the literature (1959–2012) (Continued)

| Study | Year | Gender | Disease/Infection | Antibiotic | Source |
|-------|------|--------|-------------------|------------|--------|
| Caravalho 1990 [25] | 1990 | F | RA endophthalmitis | | powder recover |
| Woolf 1990 [27] | 1990 | F | adenocarcinoma peritonitis | ampicillin | capsule death |
| Babu 1990 [30] | 1990 | M | AIDS/Kaposi’s sarcoma bacteraemia/gastroenteritis/UTI | ciprofloxacin | rattlesnake powder recover |
| Noskin 1990 [15] | 1990 | M | AIDS bacteraemia | ampicillin | rattlesnake meat recover |
| Kraus 1991 [21] | 1991 | F | SLE cholecystitis/bacteraemia | ciprofloxacin | rattlesnake capsule recover |
| Kraus 1991 [21] | 1991 | M | dermatomyositis hip septic arthritis | ciprofloxacin | rattlesnake capsule recover |
| Kraus 1991 [21] | 1991 | F | SLE knee septic arthritis | ciprofloxacin | rattlesnake capsule recover |
| Kraus 1991 [21] | 1991 | F | SLE knee/shoulder septic arthritis/sepsis | ampicillin | rattlesnake capsule recover |
| Kraus 1991 [21] | 1991 | F | leukaemia bacteraemia | ciprofloxacin | unknown recover |
| Kraus 1991 [21] | 1991 | F | Primary biliary cirrhosis vertebral osteomyelitis/UTI | ampicillin/amikacin | unknown recover |
| Kraus 1991 [21] | 1991 | F | SLE UTI | TMP/SMX | NA recover |
| Kraus 1991 [21] | 1991 | M | DM, ALS bacteraemia | TMP/SMX | rattlesnake capsule recover |
| Sharma 1992 [29] | 1992 | M | gastric cancer peritonitis | cefotaxime/gentamicin | rattlesnake pills recover |
| Cortes 1992 [26] | 1992 | M | metastatic carcinoma bacteraemia/pneumonia | aztreonam | rattlesnake meat recover |
| Hoag 2005 [17] | 2005 | F | AIDS bacteraemia/pericarditis/gastroenteritis/UTI | ceftriaxone/ciproxin | pet chicken? recover |
| Di Bella 2011 [4] | 2011 | M | Hodgkin's disease/panhypoglycobilinemia gastroenteritis | ciprofloxacin | NA recover |
| S. Kolker 2012 [9] | 2012 | F | pemphigus tibial abscess | ceftriaxone/ciproxin | iguana/snakes recover |

f female, m male, sle systemic lupus erythematosus, dm diabetes mellitus, htn hypertension, hbv hepatitis b, aids acquired immunodeficiency syndrome, dcm dilated cardiomyopathy, chf congestive heart failure, ra rheumatoid arthritis, als amyotrophic lateral sclerosis, uti urinary tract infection, tmp/smx trimethoprim/sulfamethoxazole, na not available

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Lee et al. BMC Infectious Diseases (2016) 16:746
third-generation cephalosporins might be more effective than ampicillin.

Abbreviations
AIDS: Acquired immunodeficiency syndrome; ALS: Amyotrophic lateral sclerosis; ALT: Alanine aminotransferase; CHF: Congestive heart failure; CLSI: Clinical and laboratory standards institute; CRP: C-reactive protein; CYCH: Chia-Yi Christian Hospital; DCM: Dilated cardiomyopathy; DM: Diabetes mellitus; F: Female; HBV: Hepatitis B; HTN: Hypertension; M: Male; NA: Not available; RA: Rheumatoid arthritis; SLE: Systemic lupus erythematosus; TMP/SMX: Trimethoprim/sulfamethoxazole; UTI: Urinary tract infection; WBC: White blood cell

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Authors’ contributions
YCL and JTW designed, executed, and supervised the study. YCL drafted the manuscript, and MCH and SCH helped writing of the article. SCH, HPW and YCL designed, executed, and supervised the study. YCL drafted the manuscript, and MCH and SCH helped writing of the article. SCH, HPW and YCL drafted the manuscript, and MCH and SCH helped writing of the article. SCH, HPW and YCL drafted the manuscript, and MCH and SCH helped writing of the article. SCH, HPW and YCL drafted the manuscript, and MCH and SCH helped writing of the article. SCH, HPW and YCL drafted the manuscript, and MCH and SCH helped writing of the article.

Authors’ contributions
YCL and JTW designed, executed, and supervised the study. YCL drafted the manuscript, and MCH and SCH helped writing of the article. SCH, HPW and MCL participated in collection, analysis and interpretation of the data. HLC carried out the literature review. YCL, MCH and JTW critically reviewed the manuscript. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

Consent for publication
Not applicable.

Ethics approval and consent to participate
The study was approved by the Institutional Review Board of Chia-Yi Christian Hospital (CYCH-IRB No. 104033, 06/30/2015). The IRB waived both the informed consent due to the retrospective study design and the research posing no more than minimal risk.

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References
1. Riley KB, Antoniokis D, Maris R, Leedom JM. Rattlesnake capsule-associated Salmonella arizonae infections. Arch Intern Med. 1988;148(5):1207–10.
2. Caldwell ME, Ryerson DL. Salmonellosis in Certain Reptiles. J Infect Dis. 1935;65(3):242–5.
3. Tindall BJ, Grimont PA, Garrity GM, Ezubey JP. Nomenclature and taxonomy of the genus Salmonella. Int J Syst Evol Microbiol. 2005;55(1):521–4.
4. Di Bella S, Capone A, Bordi E, Johnson E, Musso M, Topino S, Noto P, Petrosillo N. Salmonella enterica spp. arizonae infection in a 43-year-old Italian man with hypoglycemia: a case report and review of the literature. J Med Case Rep. 2011;5:323.
5. Seligmann E, Saphra L, Wasserman M. Occurrence of some unusual Salmonella types in man including a new type, Salmonella georgia. Am J Hyg. 1944;40:227–31.
6. Andrews MD. Arizona group gastroenteritis. J Okla State Med Assoc. 1970;63(9):421–5.
7. Centers for Disease Control (CDC). Arizona hinshawii septicemia associated with rattlesnake powder—California. MMWR Morb Mortal Wkly Rep. 1983;32(35):464–5.
8. Smilack JD, Goldberg MA. Bone and joint infection with Arizona hinshawii: report of a case and a review of the literature. Am J Med Sci. 1975;270(3):503–7.
9. Kolker S, Iskowton T, Yinnon AM, Lachish T. Osteomyelitis due to Salmonella enterica subs. arizonae: the price of exotic pets. Clin Microbiol Infect. 2012;18(2):167–70.
10. Bhatt BD, Zuckerman MJ, Foland JA, Poland JA, Marwah RK. Disseminated Salmonella arizonae infection associated with rattlesnake meat ingestion. Am J Gastroenterol. 1989;84(6):453-5.
11. Quismorio Jr FP, Jakes JT, Zarnow AJ, Barber D, Kitridou RC. Septic arthritis due to Arizona hinshawii. J Rheumatol. 1983;10(1):147–50.
12. Keren DF, Rawlings Jr W, Murray HW, Leonard WR. Arizona hinshawii osteomyelitis with antecedent enteric fever and sepsis. A case report with a review of the literature. Am J Med. 1976;60(4):577–82.
13. Faustein V, Yancey R, Trier P, Bodey GP. Overwhelming infection in a cancer patient caused by Arizona hinshawii: its relation to snake pill ingestion. Am J Infect Control. 1982;10(4):147–53.
14. Cone LA, Boughton WH, Cone LA, Leib LH. Rattlesnake capsule-induced Salmonella arizonae bacteremia. West J Med. 1990;153(3):315–6.
15. Noskin GA, Clarke JT. Salmonella arizonae bacteremia as the presenting manifestation of human immunodeficiency virus infection following rattlesnake meat ingestion. Rev Infect Dis. 1990;12(3):514–7.
16. McIntyre JR KE, Malone JM, Richards E, Axline SG. Mycotic aortic pseudoaneurysm with aortoenteric fistula caused by Arizona hinshawii. Surgery. 1982;91(2):173–7.
17. Hoag JB, Sessler CN. A comprehensive review of disseminated Salmonella arizonae infection with an illustrative case presentation. South Med J. 2005;98(11):1123–9.
18. Arora S, Tyagi SC. Bacteremia due to Salmonella arizonae. J Assoc Physicians India. 1976;24(7):457–8.
19. Jacobson MA, Hahn SM, Gerberding JL, Lee B, Sande MA. Ciprofloxacin for Salmonella arizonae bacteremia in the acquired immunodeficiency syndrome (AIDS). Ann Intern Med. 1989;110(12):1027–9.
20. Krag D, Shean DB. Serious human infections due to bacillus of the Arizona group. Calif Med. 1959;90(3):230–3.
21. Kous A, Guerra-Bautista G, Alarcon-Segovia D. Salmonella arizonae arthritis and septicemia associated with rattlesnake ingestion by patients with connective tissue diseases. A dangerous complication of folk medicine. J Rheumatol. 1991;18(9):1328–31.
22. Petru MA, Richman DD. Arizona hinshawii infection of an atherosclerotic abdominal aorta. Arch Intern Med. 1981;141(1):537–8.
23. Schneider L, Ellinger M, Stanchina C, Giacomelli MC, Gicquel P, Karger C, Clavert JM. Salmonella arizonae subs. arizonae bone and joints sepsis. A case report and literature review. Orthop Traumatol Surg Res. 2009;95(3):325–42.
24. Guckian JC, Byers EH, Perry JE. Arizona infection of man. Report of a case and review of the literature. Arch Intern Med. 1990;150(2):170–7.
25. Carvalhio Jr J, McMillan VM, Ellis RB, Betancourt A. Endogenous endophthalmitis due to Salmonella arizonae and Hafnia alvei. South Med J. 1990;83(9):325–7.
26. Cortes E, Zuckerman MJ, Ho H. Recurrent Salmonella arizonae infection after treatment for metastatic carcinoma. J Clin Gastroenterol. 1992;14(2):157–9.
27. Woolf GM, Runyon BA. Spontaneous Salmonella infection of high-protein noncirrhotic ascites. J Clin Gastroenterol. 1990;12(4):430–2.
28. Fleischman S, Haake DA, Lovett MA. Salmonella arizonae infections associated with ingestion of rattlesnake capsules. Arch Intern Med. 1989;149(3):701, 705.
29. Sharma J, Von Hoff DD, Weiss GR. Salmonella arizonae peritonitis secondary to ingestion of rattlesnake capsules for gastric cancer. J Clin Oncol. 1993;11(11):2288–9.
30. Babu K, Sonnenberg M, Kathpalia S, Ortega P, Swiatlo AL, Kocka FE. Isolation of salmonellae from dried rattlesnake preparations. J Clin Microbiol. 1990;28(2):361–2.
31. Canner PR, Zuckerman MJ. Salmonella arizonae in patients with AIDS along the U.S.-Mexican border. N Engl J Med. 1990;323(3):198–9.
32. Johnson RH, Lutwick LI, Huntley GA, Vosti KL. Arizona hinshawii infections. New cases, antimicrobial sensitivities, and literature review. Ann Intern Med. 1976;85(5):587–92.
33. Baron EJ, Thomson RB. Specimen Collection, Transport, and Processing: Bacteriology. In: Versalovic J, Carroll KC, Funke G, Jorgensen JH, Landry ML, Warnock D, editors. Manual of Clinical Microbiology. Washington, DC: ASM press; 2011. p. 228–71.

34. Atlas RM, Synder JW. Reagents, Stains, and Media: Bacteriology. In: Versalovic J, Carroll KC, Funke G, Jorgensen JH, Landry ML, Warnock D, editors. Manual of Clinical Microbiology. Washington, DC: ASM press; 2011. p. 272–303.

35. Laboratory C, Institute S. Performance Standards for Antimicrobial Susceptibility Testing; twentieth Informational Supplement, M100-S20. CLSI: Wayne; 2010.

36. Clinical Laboratory and Standard Institute. Performance Standards for Antimicrobial Susceptibility Testing: twenty-third Information Supplement, M100-S23. Wayne: CLSI; 2013.

37. Kwon MH, Kang MI, Chun JY, Lim HW, Yeum YS, Kang YW, Kim YJ, Kim YK. A case of neck abscess caused by Salmonella serotype D in a patient with liver cirrhosis. Yonsei Med J. 2010;51(1):128–30.

38. Jacobs C, Coss AE, Attaluri A, Valestin J, Rao SS. Dysmotility and proton pump inhibitor use are independent risk factors for small intestinal bacterial and/or fungal overgrowth. Aliment Pharmacol Ther. 2013;37(1):1103–11.

39. Wu HH, Chen YT, Shih CJ, Lee YT, Kuo SC, Chen TL. Association between recent use of proton pump inhibitors and nontyphoid salmonellosis: a nested case-control study. Clin Infect Dis. 2014;59(1):1554–8.

40. Lindsay KL, Canawati HN. Spontaneous Arizona hinshawii peritonitis in cirrhosis with ascites. Gastroenterology. 1981;81(2):349–51.

41. Wang YJ, Hwang JJ, Hsu CN, Lin LC, Hsueh PR. Bacteraemia due to ciprofloxacin-resistant Salmonella enterica serotype Choleraesuis in adult patients at a university hospital in Taiwan, 1996–2004. Epidemiol Infect. 2006;134(5):977–84.

42. Gerada J, Ganeshanathan G, Dawwas MF, Winterbottom AP, Sivaprakasam R, Butler AJ, Alexander GJ. Infectious aortitis in a liver transplant recipient. Am J Transplant. 2013;13(9):2479–82.

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