Aspiration pneumonia and challenges following the Samoa Tsunami in 2009

Tamara Ah Leong-Nowell, Foloto Leavai, Lucilla Ah Ching, Limbo Fiu, Rosemary Wyber, Mitzi Nisbet, David Jones, Tim Blackmore, Tupu Ioane-Cleverley

Abstract

On 29 September 2009, a large tsunami struck the Samoan Islands in the South Pacific Ocean, causing 142 deaths and large numbers of casualties. 199 patients presented to the emergency department within the first 72 hours. Twenty-nine patients were admitted with respiratory symptoms and histories of aspirating contaminated seawater and were diagnosed with tsunami-associated aspiration pneumonia. These patients were initially treated with empiric antibiotics based on drug availability and published experience after the Asian Boxing Day Tsunami of 2006. Antibiotic treatment was subsequently modified with sputum culture information. The good outcomes of the Samoa Tsunami patients may be attributed to early initiation of appropriate antibiotics and timely coordinated management.

Samoa is a small independent developing island nation in South Pacific Ocean with a 2009 population of 183,203 people. On 29 September 2009, a large tsunami struck the south east coast of the main island of Upolu following an offshore undersea earthquake of 8.1 magnitude. The worst affected areas were low-lying villages about 2 hours drive across the island from the capital, Apia. The Tupua Tamasese Meaole (TTM) National Hospital in Apia, was the major treatment centre for casualties from the tsunami.

142 people died following the disaster, representing 0.08% of the total population. 199 patients presented to the emergency department within the first 72 hours. This paper describes the cohort of patients who were assessed by the medical team and diagnosed with tsunami-associated aspiration pneumonia.

The National Hospital’s immediate response during the acute phase was coordinated and performed by the Samoa Disaster Medical Team. The Samoan team was supported by the Australian Quick Response Team (who arrived the day after the tsunami) and subsequently by the New Zealand Disaster and Emergency Response Team. Samoan volunteer doctors and nurses from New Zealand, Australia, United States, Canada and other parts of the world arrived in the days following the tsunami and were incorporated into the team.

This violent disaster resulted in much orthopaedic and surgical trauma, however the majority of victims had medical rather than surgical injuries. Tsunami-associated aspiration pneumonia is a unique condition which occurs when patients are submerged by tsunami waves resulting in the inhalation of saltwater, sand, foreign bodies and waste matter, usually under pressure.

Care for these patients was provided by the local staff in the TTM Medical Unit, which at the time of disaster consisted of one house surgeon, four registrars and a
general medical consultant who also assumed the role of disaster administrator. Following the tsunami, an improvised tsunami ward was immediately opened and largely run by junior medical staff. Any patient that was under the surgical team who was identified by either the anaesthetist or surgical team as having aspirated were also referred to the medical team for further assessment.

This retrospective descriptive case series describes the cohort of patients who had tsunami-associated aspiration pneumonia including the clinical characteristics, treatment and outcome. It provides an opportunity to reflect on the lessons learnt and to consider recommendations for the future.

Methods
The 29 patients admitted with aspiration pneumonia to TTM Hospital within 72 hours of the tsunami impact were included in this retrospective descriptive case series.

The diagnosis of tsunami-associated aspiration pneumonia was made in patients who were submerged, had respiratory symptoms with supporting clinical and radiological findings. All patients with aspiration pneumonia had bilateral infiltrates on chest X-ray imaging. Acute respiratory distress syndrome (ARDS) was defined as the development of bilateral infiltrates associated with poor oxygenation despite high flow oxygen and no clinical evidence of left ventricular failure. Some of these 29 patients also had tsunami related barotrauma, psychological problems, soft tissue injuries and concurrent pulmonary tuberculosis. Patients who were admitted to the surgical unit were excluded from this review, unless they were specifically referred to the medical unit for management and had a history consistent with tsunami-associated aspiration pneumonia.

A chart review was completed to obtain information on clinical characteristics, antibiotic treatment, radiological findings and outcome. Culture information is reported on sputum samples that were collected between 2 to 5 days following the tsunami. Follow-up data is also provided from clinics that occurred at two, six and 7 months following the tsunami.

Results
Of the 29 aspiration pneumonia patients identified, seven (24%) were male and the median age was 41 years (range 14–95). Five (17%) patients had oxygen saturations of less than 70% on room air at presentation. Most patients with aspiration pneumonia had multiple complications as outlined in Table 1.

Table 1. Medical diagnoses in aspiration pneumonia patients

<table>
<thead>
<tr>
<th>Aspiration pneumonia</th>
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<tbody>
<tr>
<td>ARDS</td>
</tr>
<tr>
<td>Lobar collapse</td>
</tr>
<tr>
<td>Rib fractures</td>
</tr>
<tr>
<td>Pneumothorax</td>
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<tr>
<td>Pulmonary tuberculosis</td>
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<tr>
<td>Soft tissue infections and fasciitis</td>
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<tr>
<td>Vertigo</td>
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<tr>
<td>Psychological</td>
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The radiological findings in the patients with tsunami-associated aspiration pneumonia included bilateral pulmonary infiltrates in all those admitted, rib fractures in two patients, a pneumothorax in two patients and a left lower lobe collapse in one
patient. The lobar collapse was presumably due to the aspiration of a foreign body and resolved with physiotherapy.

Five patients (17%) out of the 29 included in the cohort had presumed acute respiratory distress syndrome (ARDS) and all of these patients had oxygen saturations of less than 70% at presentation.

A series of cases and medical issues that were observed following the tsunami are described below:

- A 21-year-old male with severe respiratory distress initially improved clinically and radiologically on broad spectrum antibiotics and high flow oxygen, but then acutely deteriorated 6 days later. A repeat chest X-ray showed interval changes of widespread reticulonodular infiltrates. He had a brief period of non-invasive ventilation in the form of CPAP provided by a borrowed machine from outside the hospital. This was poorly tolerated due to poor fitting of the only available nasopharyngeal interface and was discontinued a short period later.

  Seventy-two hours after discontinuing CPAP he had a further acute deterioration due to a large pneumothorax that required an intercostal drain. Throughout his hospital admission he expectorated black sand mixed with purulent sputum. His sputum cultured *Citrobacter* spp. and *Pseudomonas aeruginosa*. On day 12 intravenous meropenem 1g 8 hourly was commenced with clinical improvement. Arterial blood gases were not able to be performed.

- A 95-year-old presented more than 36 hours after the tsunami died after she declined ongoing active medical intervention. The remaining 28 patients all survived to discharge from hospital.

- One patient was observed to have bilateral upper lobe infiltrates at presentation and an additional diagnosis of smear positive tuberculosis was also made.

- Skin and soft tissue infections were common; one patient was initially admitted to the high dependency unit (HDU) with aspiration pneumonia and on day 3 was also found to have thigh fasciitis and was transferred to New Zealand on the next available flight. The other one was diagnosed with perineal infection and required a prolonged admission.

- Vertigo was one of the most common complaints after the third day following the tsunami and was attributed to eardrum trauma from the tsunami waves.

- There were a number of tsunami medical patients who had an acute stress reaction and for these patients psychological concerns were an immediate and ongoing priority.

**Microbiology**—Sputum was cultured from 15 of the initial patients who presented with aspiration pneumonia (Table 2). An organism was subsequently identified from 12 of these cultures. Five patients had polymicrobial cultures. *Streptococcus* spp. was identified in seven patients and *Pseudomonas aeruginosa* in six cultures. Three
patients grew *Citrobacter* spp., two cultured *Proteus* spp., and there was one culture each of *Klebsiella* spp., *Pantoea* spp., and *Enterobacter* spp.

### Table 2. Isolates cultured from sputum from tsunami aspiration pneumonia patients

<table>
<thead>
<tr>
<th>Species</th>
<th>N</th>
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<tbody>
<tr>
<td><em>Streptococci</em> spp.</td>
<td>7</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>6</td>
</tr>
<tr>
<td><em>Citrobacter</em> spp.</td>
<td>3</td>
</tr>
<tr>
<td><em>Proteus</em> spp.</td>
<td>2</td>
</tr>
<tr>
<td><em>Klebsiella</em> spp.</td>
<td>1</td>
</tr>
<tr>
<td><em>Pantoea</em> spp.</td>
<td>1</td>
</tr>
<tr>
<td><em>Enterobacter</em> spp.</td>
<td>1</td>
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</tbody>
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**Antibiotic treatment**—Several antibiotics were used as initial empiric treatment however this was rationalised by day 2 to a standard four antibiotic regimen (IV gentamicin, IV cefuroxime 750mg 8 hourly, oral metronidazole 400mg 6 hourly and oral cotrimoxazole 960mg 12 hourly) for all patients that required hospital admission due to aspiration pneumonia.

All patients with respiratory distress at initial presentation had received dexamethasone and frusemide however this was discontinued after 24 hours. Patients were discharged on either oral amoxycillin-clavulanate 625mg three times daily or oral cotrimoxazole 960mg twice daily unless cultures suggested that other treatment was required such as ciprofloxacin 500mg twice daily to treat *Pseudomonas aeruginosus*.

Expectant treatment was recommended for vertigo. Intervention for psychological sequelae was provided for patients with persistent concerns as required.

**Follow-up**—Three follow-up clinics were conducted for aspiration pneumonia patients at 2, 6 and 7 months following the tsunami. Chest X-rays were repeated in all patients at 2 months, and in any patient who had ongoing symptoms at 6 and 7 months following the tsunami.

Only one of the 29 patients required a further admission shortly after their initial discharge and was diagnosed with both a psoas abscess and septic arthritis of the ankle. This patient had severe respiratory compromise at the time of the initial admission and these subsequent infections were either due to secondary seeding or suppression of these infections due to antibiotic treatment for pneumonia so that they were not identified until after all antibiotic treatment was stopped. He had normal saturations (100% on room air) at follow-up but had persisting extensive small nodules on chest X-ray.

Seventeen (59%) patients attended the 2-month follow-up clinic. Eleven (38%) patients reported ongoing respiratory symptoms predominantly with cough and sputum production. A further three (10%) patients reported weight loss following the tsunami. Most patients had resolution of chest X-ray abnormalities but a number had persisting nodular infiltrates or peri-bronchial inflammation.
Thirteen (47%) patients returned for a follow-up assessment at 6 months. Only those with continuing cough and or dyspnoea were asked to be followed up by the Respiratory specialist the following month. All those seen had recovered both clinically and radiologically including the patient with pulmonary tuberculosis. To date there have been no identified long-term pulmonary complications.

**Discussion**

The immediate use of antibiotic polytherapy was based on the pathogens that had been identified as causing aspiration pneumonia and skin infections in the 2004 Boxing Day Asian Tsunami. Tsunami-associated aspiration pneumonia in Asia was complicated by infection with multi-resistant organisms and *Burkholderia pseudomallei*, the latter of which has not previously been reported in Samoa.

Given limited local pathogen data, the medical team asked tsunami patients where they were found; many recalled being rescued on land used for pigsties, refuse tips, septic tanks, cemeteries, or the road. Empirically, the initial four antibiotics used provided cover for water borne pathogens such as *Vibrio* and *Aeromonas*, plus other potential pathogens including *Pseudomonas* and *Nocardia*.

Co-trimoxazole was used to cover for *Nocardia* which is commonly found in soil. Unlike the Boxing Day Asian Tsunami, carbapenem antibiotics are not routinely available in Samoa so were not used except for in one case of the young man with complicated pulmonary infection who failed to settle on available treatment.

The sputum culture information provided by the Samoan microbiology laboratory was invaluable for targeting ongoing antibiotic treatment. The laboratory was not able to test for *Nocardia* but did identify a number of patients who had pneumonia due to Enterobacteriacae including a number of organisms with potential for inducible beta-lactamase activity (sometimes referred to as “ESCAPPM” organisms).

Streptococcal species were also identified from sputum in a number of patients. These organisms were not speciated and may have represented normal oral flora rather than a being a pathogenic organism.

In the course of writing this article a retrospective literature review was performed to compare the Samoa experience with international experience post tsunami and confirmed that the Boxing Day Tsunami literature was the only information available to assist our empirical antibiotic treatment.

It was difficult to know how much Indian Ocean microbiology data could be extrapolated to the Samoa situation but it was assumed that *Vibrio* might be a contributing pathogen. It was not possible to locate any aspiration pneumonia microbiology relating to the Papua New Guinea tsunamis of 1998 and 2000 that would have provided relevant Pacific experience.

Of particular concern was *Burkholderia pseudomallei* which had caused a number of severe cases of melioidosis in the Indian Ocean tsunami setting. This Gram-negative bacterium is endemic in soil and surface water of South East Asia and North Australia and cases have been reported nearby Papua New Guinea and New Caledonia. Diabetes is an important risk factor for severe necrotising pneumonias and Samoa had 23.1% of the adult population in a 2002 survey.
The majority of the Samoa Tsunami patients who were admitted to hospital for surgical injuries had been submerged and had also inhaled contaminated seawater. Nevertheless, their trauma injuries took precedence over their respiratory problems and it is possible that the number of patients with aspiration pneumonia may have been greater than were clinically diagnosed. These patients received similar empirical antibiotic treatment as those with aspiration pneumonia that would have been sufficient to treat pulmonary infection.

A number of key challenges were identified as listed below:

- The use of dexamethasone in aspiration pneumonia is not usually recommended, however it was administered to this cohort for the initial 24 hours and the outcomes were generally good.
- High flow oxygen was routinely used however there was no established facility to use invasive or non-invasive ventilation. An attempt was made to establish one severely hypoxic patient who was not maintaining adequate oxygen saturations despite high-flow oxygen on non-invasive ventilation by using a donated CPAP machine. There may be benefits to having non-invasive ventilation available in future emergencies.
- Treatment was largely empiric for most patients but it was presumed that there may have been contributing Gram negative and waterborne organisms. The large influx of acutely unwell patients meant that all clinical services including the microbiology laboratory were stretched beyond capacity. Antibiotic treatment was rationalised as culture information became available. Laboratory equipment failure added to the challenges with renal function and arterial blood gas tests not being available for the initial 10-day period. Gentamicin levels cannot be performed in Samoa and so gentamicin was discontinued as soon as clinical response was observed but was continued in patients with severe sepsis.
- The Radiology Department resources were adequate, but many patients had portable bedside chest X-rays performed with anterior posterior views limiting the clarity of images especially in obese patients.
- Codeine phosphate and paracetamol were the only readily available analgesics for severe chest-wall pain. Poor analgesic control limited physiotherapy and potentially delayed recovery in some patients.
- Regular and effective chest physiotherapy was essential for the initial management of aspiration pneumonia but was limited as there was only one physiotherapist for the entire hospital.

Lessons from the Samoan Tsunami—Most tsunami victims were submerged in contaminated seawater. Respiratory problems with lung injuries and ARDS predominated and early onset of sepsis and necrotizing fasciitis complications can occur. A number of infections involved more than one organism. Infections due to atypical organisms and fungi were not reported from the Samoa Tsunami and although some of these would require a specialised laboratory to identify it was reassuring that all but one patient (who had extensive pneumonia) responded to empiric therapy that did not include antifungal treatment.
Treatment of surgical injuries tended to be undertaken with urgency, and it is important not to overlook accompanying immersion lung injury. Other cohorts have reported that patients with delayed diagnosis of tsunami aspiration pneumonia generally have worse clinical outcomes.\textsuperscript{15}

The internet literature search of previous tsunami experiences was very helpful given most medical workers have no prior experience of tsunami disasters. However there were difficulties in accessing many of the desired articles due to subscription only databases. Local staff recommend the establishment of a single international database for the management of medical problems for tsunami victims based on previous tsunami evidence data that is readily available and easily accessible at a time of need.\textsuperscript{15}

Prompt discussions with infectious disease (ID) physicians, locally or internationally, at an early stage are crucial for local practitioners. In country projects to identify common local pathogens and to determine antibiotic sensitivities would be invaluable, particularly in resource limited countries where there may be a scarcity of antibiotic choices. Knowledge of local antibiograms would also assist in improving daily clinical practices.

Clear lines of communication between clinicians, Ministry of Health and disaster organisations, both locally and internationally, is important to help facilitate access to required resources during the initial acute period. Our team presented a list of required medical needs to the disaster team coordinators on day 3.

Local doctors generally have the best understanding of the local health situation as well as resource constraints. The role of international health professionals should be to enhance local capacity and to provide expert knowledge to assist the local medical personnel.\textsuperscript{15}

Few health professionals came with prior tsunami experience and knowledge, therefore briefing at the earliest opportunity is essential. The medical team was able to inform newly arrived colleagues on the nature of tsunami injuries together with our treatment approach to help guide management of these patients.\textsuperscript{3}

Generally, when international disaster health teams depart, the devastated country is left with the enormous task of dealing with continuing and additional problems in the medium and long term. Hence links with local Primary Health Care Providers were enhanced by quickly producing a “Post-Tsunami Medical Information Booklet” and antibiotic guidelines to raise awareness and guide management of tsunami related medical problems.\textsuperscript{3}

**Recommendations**—The ideal medical team should consist of physicians (General, Infectious Disease, Respiratory), microbiologists and physiotherapists. Support should be provided by a laboratory with regard to the identification of atypical and seawater borne pathogens. Antibiotics such as a carbapenem, clindamycin and co-amoxicillin-clavulanate should be rapidly available. Equipment such as pulse oximeters, non-invasive ventilation, chest drains and possibly a bronchoscope need to be at hand.

Managed coordination and streamlined procurement and allocation of appropriate resources are essential. The local Internal Medicine Unit, in conjunction with the
overseas physicians, played an important early strategic role in the management of patients with tsunami related respiratory and medical problems in a disaster situation where resources are limited.

Conclusions

Tsunami patients admitted with aspiration pneumonia in the Samoa disaster had very good outcomes for these patients, which can be explained by the early initiation of appropriate treatment and antibiotics provided by a well coordinated local team. This management approach was driven by necessity, locally available resources and the application of basic clinical practice guided by overseas expert knowledge. Literature reviews support the interventions taken.

This paper illustrates the importance of sharing tsunami experiences both locally and internationally to improve disaster management response and practice. Acquired knowledge, expertise, resources and lessons learnt should be integrated into disaster response policies in tsunami prone regions. Local medical staff is fundamental to the success of initial and ongoing responses to any future disasters.

Competing interests: None declared.

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