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An outbreak of *Salmonella* Muenchen gastroenteritis after consuming wild hunted kangaroo, Northern Territory, Australia, 2024

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# Abstract

An outbreak of salmonellosis occurred in August 2024 after consuming wild hunted kangaroo in a remote area of the Northern Territory (NT), Australia.

We conducted an outbreak investigation via telephone and face-to-face interviews, using a standardised questionnaire that recorded symptoms and exposures to foods and activities prior to onset of symptoms. A confirmed outbreak case was defined as anyone with laboratory confirmed *Salmonella* Muenchen infection who was part of a group of people who shared meals on 25–26 August 2024. A probable outbreak case was defined as anyone who was part of a group of people who shared meals on 25–26 August 2024 and subsequently experienced diarrhoea, in the absence of a laboratory test.

Of the seven members of the group who shared meals, all became ill (attack rate 100%); three were confirmed cases and four were probable cases. The median age was 32 years (range 23–65 years); six (86%) were male. The median incubation period was 24 hours (range 6–30 hours). The most commonly reported symptoms were diarrhoea (100%, 7/7) and abdominal pain (86%, 6/7). Two cases were admitted to hospital, both for an overnight stay; all recovered.

All seven cases consumed the same meal – a single, locally hunted and butchered kangaroo. Contamination likely occurred due to unsafe butchering, storage, transportation and insufficient cooking of the meat. This outbreak highlights the risks of contamination of game meat (in this case kangaroo) with *Salmonella*. Those preparing hunted meat should wash hands and knives regularly while butchering an animal to avoid contamination; should store butchered meat below 5 °C to avoid bacterial growth and cook foods thoroughly to kill microbes. We estimate that the cost to society of this outbreak was 9,810 Australian dollars.

Keywords: *Salmonella* Muenchen; gastroenteritis; salmonellosis; foodborne disease; kangaroo; hunting

# Introduction

Salmonellosis is an illness, caused by the *Salmonella* bacterium, which commonly manifests as diarrhoea (which may be bloody), abdominal pain, fever, nausea and sometimes vomiting.1 *Salmonella* bacteria are carried in the gastrointestinal tracts of many animals including birds, reptiles, amphibians and mammals.1 A person with salmonellosis typically becomes ill 6–72 hours after ingesting the bacterium, which can be through direct or indirect contact with a contaminated environment, or more frequently through the ingestion of contaminated food which is typically raw or undercooked meat or eggs, or contaminated raw fruits or vegetables.1 *Salmonella enterica* subsp. *enterica* ser. Muenchen (*S*. Muenchen) is not uncommon in the Northern Territory (NT) of Australia. Between 2014 and 2023, eighty-seven notifications were received in the NT, with 30/87 (34%) occurring in the vast Central Australian region (Barkly and Alice Springs regions) despite only approximately 20% of the NT population living in this area of the outback.2 About 34% of all *S*. Muenchen notifications in the NT occurred in children under 5 years of age, with the majority of these assumed to be environmentally acquired.3 Known reservoirs of *S.* Muenchen include kangaroos,4 wallabies,5 snakes,5 and geckos.6

There have been previous foodborne outbreaks of *S*. Muenchen associated with pork products in Germany,7 alfalfa sprouts in the United States of America (USA),8 of unknown aetiology in a paediatric hospital in the United Kingdom,9 and with hunted turtle meat in the NT.10

Kangaroo meat has long been a staple food of Australia’s First Nations people and has become a popular meat amongst non-Indigenous Australians in recent decades. Kangaroos are known to harbour *Salmonella*.4,11,12 Foodborne disease outbreaks epidemiologically linked to consumption of kangaroo meat have occurred in Australia, with an outbreak of toxoplasmosis in Queensland;13 an outbreak of Shiga-toxin producing *Escherichia coli* in the NT;14 and an outbreak of salmonellosis (*S*. Saintpaul) in Western Australia.15

On 30 August 2024, the NT Centre for Disease Control (NT CDC) was alerted to a possible outbreak of salmonellosis (at that stage untyped) among people who had consumed wild hunted kangaroo on 25 and 26 August 2014. This was detected while investigating routine salmonellosis notifications; three cases separately attended the Alice Springs Hospital Emergency Department (ED) and treating clinicians reported that they were from a larger group who had consumed hunted kangaroo. We initiated an outbreak investigation in order to ascertain the cause of illness and to prevent further cases.

# Methods

## Epidemiological and environmental investigation

We confirmed the existence of the outbreak by administering a standardised salmonellosis case investigation questionnaire to the first two notified salmonellosis cases; the form recorded details on symptoms, health-seeking behaviour, food and activity exposures and to identify further cases. Once the existence of an outbreak was confirmed, we undertook an outbreak investigation in order to determine which food was associated with illness, and to find and prevent further cases. We administered the same standardised salmonellosis case questionnaire to all cases as they were identified.

A confirmed outbreak case was defined as anyone with laboratory-confirmed *S*. Muenchen infection who was part of a group of people who shared meals on 25–26 August 2024. A probable outbreak case was defined as anyone who was part of a group of people who shared meals on 25–26 August 2024 and subsequently experienced diarrhoea, in the absence of a laboratory test.

Data were collected and analysed in Microsoft Excel 2016 (Microsoft, USA). We conducted descriptive analysis by calculating frequencies, proportions, medians and ranges.

The preparation, storage and cooking processes of the wild hunted kangaroo were investigated. There was no environmental inspection undertaken of the site where the meat was butchered due to its remoteness; no leftover kangaroo meat was available for microbiological sampling.

We estimated the cost of this outbreak in Australian Dollars (AUD) using the Food Standards Australia New Zealand – Australian National University Foodborne Illness Costing Tool.16,17

Ethics approval was not sought for this investigation as it was conducted under the auspices of public health legislation.18,19

## Laboratory investigation

Human faeces sampled were cultured using standard techniques (microscopy, culture and sensitivity). Additionally, rotavirus, adenovirus, norovirus, sapovirus and astrovirus were tested by polymerase chain reaction (PCR) and *Cryptosporidium* was tested for using an antigen detection test. When *Salmonella* was cultured, isolates were typed using whole genome sequencing (WGS) on the Illumina NextSeq2000 platform at Territory Pathology, Darwin. Sequence reads were filtered and trimmed with fastp (version 0.23.4)20 before genome assembly with Shovill (version 1.1.0).21 *In silico* serotyping was conducted on draft genome assemblies using the *Salmonella In Silico* Typing Resource (SISTR) tool (version 1.1.1).22 Pairwise single nucleotide polymorphism (SNP) distances were calculated using split k-mer analysis (version 1.0)23 and Snippy (version 4.6.0).24

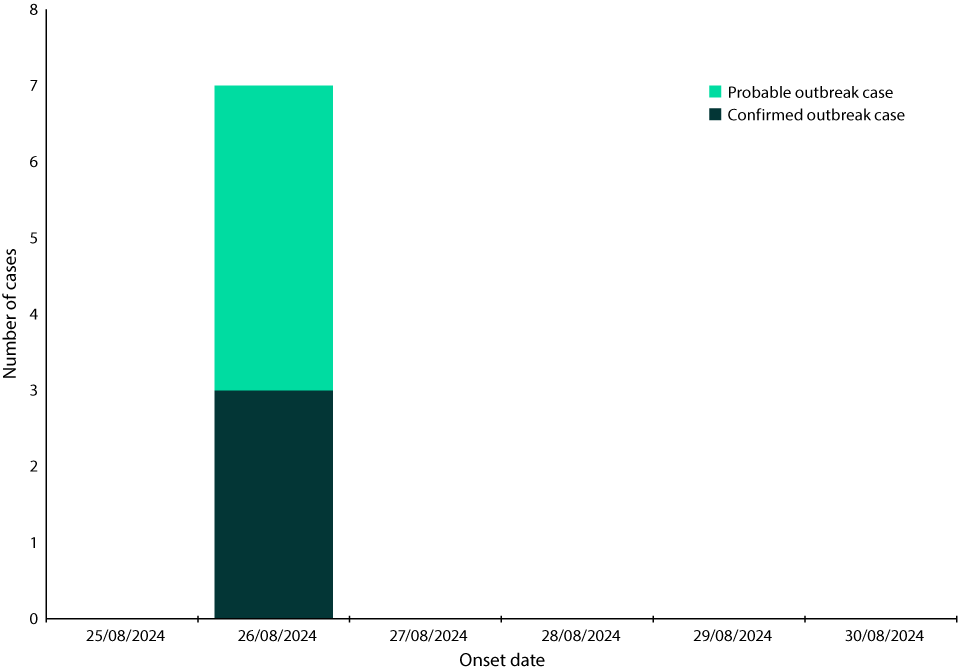
# Results

## Epidemiological and environmental investigation

We contacted 6/7 members (response rate 86%) of the group who shared meals; all became ill (attack rate 100%). One case was uncontactable but family members were able to provided details of their symptoms and exposures. Three people submitted faeces samples and had laboratory confirmed *S*. Muenchen infection; another four people met the probable case definition. The median age was 32 years (range 23–65 years); six cases (86%) were male. Three cases presented to the ED, of whom two were admitted to hospital for an overnight stay.

The most commonly reported symptoms were diarrhoea (100%, 7/7) and abdominal pain (86%, 6/7). All seven cases were known to each other and consumed the same meal: a single, locally hunted and butchered kangaroo. There was no other common food or drink consumed apart from the kangaroo. The median incubation period was 24 hours (range 6–30 hours). The epidemic curve was typical of a point source salmonellosis outbreak (Figure 1).

Figure 1: Epidemiological curve of outbreak cases by onset day after consuming wild hunted kangaroo in the Northern Territory, Australia, August 2024 (n = 7)



A large red kangaroo (*Macropus rufus*) was killed and disembowelled late on the evening of 24 August 2024 by three hunters, in the bush approximately 35 km outside Alice Springs. The carcass was left in the back of a ute (utility vehicle; i.e., a pick-up truck) at that location until it was cooked rare in an earth oven25 late on the following morning of 25 August 2024. The three hunters first ate the meat at this point. The rare cooked meat was then transported into Alice Springs at ambient temperature and two further cases ate the meat on the afternoon of 25 August 2024. The uncooked organs of the kangaroo were washed and together with the remaining rare meat were refrigerated on the afternoon of 25 August 2024. On the morning of 26 August 2024, the internal organs were boiled and together with the rare meat were distributed to a second household where two more people ate the rare meat and all became unwell. The first four cases began experiencing symptoms at approximately 6 pm on 26 August 2024. The group recognised the kangaroo meat was likely the cause of their illness. The first household immediately discarded the remaining kangaroo meat. Members in the second house also discarded the kangaroo meat but only after nine members of that household ate a stir-fry meal that contained the kangaroo meat, but cooked thoroughly. None of the nine people who ate this meal with the thoroughly cooked meat became unwell.

On 25 August 2024, Alice Springs observed an unseasonably high minimum overnight minimum temperature of 18 °C (mean August minimum temperature 5.9 °C),26 with temperatures reaching 28.5 °C by 9 am and 32.9 °C at 3 pm.27

We estimated the cost of this outbreak to be 9,810 AUD, consisting of: pain and suffering (1,140 AUD), non-fatal productivity losses (3,840 AUD), and direct losses (e.g. healthcare costs, medications, diagnostic testing, pharmaceutical costs, etc.) of 4,820 AUD.

## Laboratory investigation

The three isolates of *S*. Muenchen all clustered closely (< 5 SNPs), which was highly suggestive of a point source outbreak. No kangaroo meat was available for microbiological testing.

# Discussion

Kangaroo meat was epidemiologically implicated as the likely source of this salmonellosis outbreak and was eaten by all cases. The epidemic curve, timing of the outbreak, and environmental investigation supported this. Kangaroos are known carriers of *Salmonella* bacteria. Contamination of hunted kangaroo meat can occur when the same knife is used to clean and eviscerate the animal and then is re-used for butchering. To reduce the risk of contamination of hunted meat, it is important to clean hands and knives with soap and water; wash hands and knives regularly while butchering an animal; avoid contaminating the carcass with dirt, plant-life, and bacteria from the gut; and protect the carcass from other wildlife. Soap and water was not available at the remote site where this kangaroo was cleaned/eviscerated and left overnight.

After the likely contamination of the meat with *Salmonella* during cleaning, the environmental investigation observed that the remote site where the kangaroo carcass was left overnight experienced temperatures far above 5 °C which is recommended for safely storing and transporting raw meat.28 This likely promoted *Salmonella* growing to hazardous levels in the meat. The following day the meat was only cooked ‘rare’, which was insufficient to kill all bacteria29 which existed in the meat and could have possibly expedited the contamination of the meat through further heating. The meat was then transported later that day at temperatures approaching 35–37 °C, which is the optimal growth temperature of *Salmonella*.30,31,32 Those who ate the rare meat last on 26 August, had the shortest incubation periods which may indicate higher levels of contamination. The nine people in the second household who ate meat cooked thoroughly in a stir-fry and who didn’t become unwell are evidence that cooking the meat thoroughly killed the *Salmonella* and made the meat safe to consume. This investigation identified factors that contributed to the outbreak which were consistent with a previous outbreak of *S*. Muenchen in the NT in 2017 which was associated with consumption of sea turtle,10 i.e. incomplete evisceration, lack of refrigeration of meat and insufficient cooking.

A major limitation of the investigation was that there was no leftover kangaroo meat available for sampling. In any case, microbiological testing of food in Central Australia is difficult due to the absence of a local food testing laboratory and the prohibitive cost of sending samples interstate for testing.

Information was obtained about 7/7 of the people who ate the kangaroo, and there were no reports of illness in other family or household members who did not eat the undercooked kangaroo.

# Conclusion

We conclude that this outbreak of *S*. Muenchen was epidemiologically associated with eating contaminated kangaroo meat. Contamination likely occurred during evisceration/butchering and was exacerbated by temperature abuses during storage and transport. Inadequate cooking failed to kill microbes and may have in fact contributed to further growth. To prevent contamination of hunted kangaroo meat, hands and knives should be cleaned with soap and water. Hands and knives should be washed regularly while butchering an animal, to avoid contaminating the carcass. Butchered meat should be stored and transported in a clean environment below 5 °C in order to reduce the risk of contamination. It is advisable to cook kangaroo meat completely through (e.g. to 72 °C) to ensure killing of all microbes. These preventative measures should be adhered to and planned for, regardless of remoteness.

It is important to investigate outbreaks of *Salmonella* in order to identify risks, to undertake appropriate public health action and to promote public safety.

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