Use of verbal autopsy for establishing causes of child mortality in camps for internally displaced people in Mogadishu, Somalia: a population-based, prospective, cohort study

Andrew J Seal, Mohamed Jelle, Carlos S Grijalva-Eternod, Hani Mohamed, Raha Ali, Edward Fottrell

Summary

Background People in humanitarian emergencies are likely to experience excess mortality but information on the causes of death is often unreliable or non-existent. This study aimed to provide evidence on the causes of death among children younger than 5 years in camps for internally displaced people in southern Somalia, during periods of protracted displacement and emergency influx amid the 2017 drought and health emergency.

Methods We did a prospective, cohort study in 25 camps in the Afgooye corridor, on the outskirts of Mogadishu, Somalia. All internally displaced children aged 6–59 months were included and followed up with monthly household visits by community health workers. Nutrition, health, and vaccination status were ascertained and verbal autopsy interviews were done with the caregivers of deceased children. We calculated death rates in these children and used verbal autopsy to establish the cause-specific mortality fraction (CSMF). Bayesian InterVA software was used to assign likely causes to each death.

Findings Between March, 2016, and March, 2018, 3898 children were followed up. 153 deaths were recorded during 34 746 person-months of observation. The death rate among children younger than 5 years exceeded emergency thresholds (>2 deaths per 10 000 children per day), reaching a peak of seven deaths per 10 000 children per day during the emergency influx. Verbal autopsy data were gathered for 80% of deaths, and the CSMF for the three leading causes of death were diarrhoeal diseases (25·9%), measles (17·8%), and severe malnutrition (8·8%). Coverage of measles vaccination during the first 3 months of the emergency was 42% and the CSMF for measles doubled during the influx. During protracted displacement, symptoms that could be attributable to HIV/AIDS related deaths accounted for 1·6% of the CSMF.

Interpretation It is feasible to establish a health and nutrition surveillance system that ascertains causes of death, using verbal autopsy, in this humanitarian context. These data can inform policy, response planning, and priority setting. The high mortality rate from infectious diseases and malnutrition among children younger than 5 years suggests the need for strengthening a range of public health interventions, including vaccination and provision of water, sanitation, and hygiene.

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Institute for Global Health, University College London, London, UK (A J Seal PhD, M Jelle MSc, C S Grijalva-Eternod MSc, E Fottrell PhD); **Concern Worldwide Somalia, Mogadishu, Somalia** (H Mohamed BSc, R Ali BSc)

Correspondence to: Dr Andrew J Seal, Institute for Global Health, University College London, London WC1N 1EH, UK **a.seal@ucl.ac.uk**

Introduction

There are currently approximately 41·3 million people worldwide who are internally displaced by conflict and violence.[1] In 2018, there were an estimated 28 million new internal displacements caused by conflict and disasters, with 36% of these occurring in sub-Saharan Africa. Within Somalia, 1·3 million people were new displacements that were caused by ongoing protracted conflict and natural disasters in 2017, and there was a further 1·1 million internally displaced people (IDP) in 2018.[1,2]

People in humanitarian emergencies are likely to have severe health consequences caused by lack of access to food, water, shelter, sanitation, and medical care, leading to a substantial burden of excess mortality.[3,4] Refugees and IDP typically have high mortality rates during the period immediately following their migration. In Africa, crude mortality rates have sometimes been as high as 80-times the baseline rates.[4]

Death rates are usually highest in children aged 5 years or younger. Somalia is one of the countries with the highest mortality rates among this age group.[5] Before the drought emergency of 2017, surveys by the Food Security and Nutrition Analysis Unit of Somalia (FSNAU) showed that, of all the areas where data were available, IDP in Mogadishu had the highest death rate among children younger than 5 years (1·5 deaths per 10 000 people per day).[6]

Collection of data on causes of death is essential for public health planning, resource allocation, and

Research in context

Evidence before this study

During humanitarian emergencies there is usually an increase in the mortality rate of the affected population, with children younger than 5 years often having the highest rates of excess mortality. Although there are established methods to quantify death rates, there is comparatively less data available on the causes of death in these contexts. In low-income countries there is low coverage of vital registration, and this situation is exacerbated in disasters and conflict. WHO supports the development and deployment of verbal autopsy as a tool to fill gaps in the data available on the causes of death.

We did a literature search and had discussions with key informants to explore what evidence existed on the use of verbal autopsy in emergency contexts. We found no published evidence on its use in these contexts, although various other questionnaires have been developed and used in household surveys to determine the cause of death. Previous studies have suggested that infectious disease outbreaks, such as measles, are often the primary cause of excess child mortality during food security crises.

Added value of this study

This study provides new evidence on the causes of child death during a humanitarian emergency in Somalia. By establishing and maintaining a household surveillance system for 2 years we were able to track patterns of mortality and the causes of death in a population living in camps for internally displaced people on the outskirts of Mogadishu, Somalia. We observed seasonal differences in the death rate during the protracted displacement phase with a cyclical pattern in mortality that appeared to be linked with recorded rainfall. During a period of acute emergency influx in 2017 we observed a marked increase in the death rate and measles became an important cause of elevated mortality. Our observations reiterate the importance of ensuring basic public health measures such as vaccination and therapeutic feeding are implemented during food security and displacement crises.

Implications of all the available evidence

The study results show the utility and feasibility of using verbal autopsy during a humanitarian emergency. Our approach can provide accurate and timely information to better identify the main threats to public health and guide which interventions should be prioritised to prevent excess mortality. Further research to scale up this approach in different contexts is warranted.

monitoring and evaluation of programmes. However, very little information is available on the causes of death in conflict and internal displacement settings.[7] Although many low-income and middle-income countries do not have effective vital registration and cause of death surveillance systems, the dearth of cause-specific mortality data is arguably greater in humanitarian settings, where any existing surveillance systems are likely to be weakened or interrupted. Additionally, most deaths occur at home and burial arrangements are often made on the same day, which adds to the difficulty of counting deaths and determining cause in contexts such as Somalia.[8]

Verbal autopsy is a feasible alternative for assessing causes of death in such settings.[9,10] The process of interviewing close caregivers of the deceased to gather data on the symptoms, signs, and circumstances preceding death, and then using these data to determine the probable causes of death, has been widely used in research settings.[11–14] The use of verbal autopsy in humanitarian settings was previously hampered by several factors including the long duration that field workers took to complete verbal autopsy interviews. In Somalia, the FSNAU first piloted the use of verbal autopsy in their routine surveys in 2011–12 but stopped because of the complexities in setting up and running the data collection and analysis system.[6]

Over the past 10 years, WHO and partners have developed standardised survey tools and automated interpretation methods to allow widespread, routine use in low-resource settings.[15] Using these tools, it is now possible to administer a verbal autopsy interview in less than 30 min and immediately identify probable causes of death.[16] This study describes the application of verbal autopsy to determine the causes of death among children aged between 6 and 59 months in IDP camps in the Afgooye corridor, Mogadishu, during periods of protracted displacement and emergency influx.

Methods

Study design and participants

A Nutrition and Mortality Monitoring System (NMS) was initially set up in 2016 during a trial of unconditional cash transfers on the risk of acute malnutrition in internally displaced children.[17] The study was done in IDP camps located in Weydow area, Deyniile district, Mogadishu, part of the so-called corridor that runs between Mogadishu and the town of Afgooye, Somalia. This area hosts the majority of IDP in the greater Mogadishu area. The camps are privately run settlements that are often overcrowded, have inadequate basic sanitation and health services, and the residents are susceptible to eviction. The IDP residing in these camps are primarily agropastoralists and riverine farmers from marginalised clans or minority groups from Bay, Bakool, and the Shabelles.[18,19] The primary livelihood sources within the camps are casual labour, petty trading, and humanitarian assistance from local and international organisations.

All internally displaced children aged 6–59 months who were living in the study IDP camps were included and followed up with monthly household visits.

The study received ethical approval from the Ministry of Health and Human Services of the Federal Government (Mogadishu, Somalia; reference MOH&HS/DGO/0548/August/2016) and from the Research Ethics Committee at University College London (London, UK; project 1822/003). Verbal autopsy interviews were done after obtaining informed verbal consent from caregivers of the deceased.

Procedures

During the first phase of data collection, 20 IDP camps were included in the NMS. This period lasted from April, 2016, until February, 2017, and was characterised by relative stability, with low rates of migration in and out of the camps included in the surveillance system. The onset of food and health crises in 2017 led to a rapid influx of new arrivals into the Afgooye corridor area and the establishment of new IDP camps. To provide sentinel site data during the evolving emergency we adapted the NMS between May and June, 2017, by excluding five camps from the system and recruiting five new camps that had been established to accommodate for new arrivals. Camps were prioritised for deselection if they had a decreasing population or if the camp had a higher than average number of non-response households. This purposive sampling allowed us to monitor the situation in the new arrival camps and track the effect of the emergency on pre-existing IDP camps containing long-stay (ie, >1 year) residents. The two main selection criteria for the five new camps were: camps must be receiving humanitarian assistance from Concern Worldwide, and camps must have the most recent (ie, within the past month) IDP arrivals. Monthly household enumeration revealed that few new arrivals settled within pre-existing camps. By September, 2017, the monthly NMS revealed that the acute emergency was over and the situation had returned to the status of protracted displacement. Monthly NMS data collection was undertaken by six teams of community health workers, closely supervised by Concern Nutrition Supervisors, and the NMS Coordinator. All households in the study camps were included and data on the demographics of household members such as sex, age, status (ie, present, absent, in hospital, moved away, dead, or other), clan, and region of origin were collected. Age was calculated using the date of birth taken from health record cards or, when this was not available, a local events calendar. The details of the NMS design and sampling method have been described elsewhere.[17]

New arrivals were defined as children who were present for the first time during the monthly data collection round. Person-time was calculated in days using dates of the previous and current interview. When the child was no longer present but had been present and alive during the previous visit, the exposure period was estimated as 15 days. The same estimated period was used when a child was found present and alive but had been absent previously.

All children aged 6–59 months had a single mid-upper arm circumference (MUAC) measurement taken and were assessed for bipedal pitting oedema. MUAC measurements were done using a flexible measuring tape at the midpoint between the shoulder and elbow of the left arm. Children identified as malnourished (MUAC <125 mm), or who had bilateral oedema were referred to nutrition centres for treatment. During the emergency influx phase, additional questions on vaccination status, suspected measles, and suspected acute watery diarrhoea or cholera were asked.

Suspected prevalent cases of measles were ascertained by a NMS community health worker checking for fever and maculopapular rash plus cough or coryza (ie, runny nose) or conjunctivitis (ie, red eyes), as per the WHO measles case definition.[20] Suspected cases of acute watery diarrhoea or cholera were assessed by asking if a child had three or more loose or watery stools per day, based on the case definition by the FSNAU.[21] Routinely, each of the six NMS community health worker teams collected information from 20–30 households each day. Questionnaire data were collected on paper forms and double entered into Microsoft Excel 2016. Any discrepancies between the two entered datasets were explored, and data cleaned as necessary by referring back to the original data entry forms, or confirming data by additional field visits, or both.

We identified all children who died following registration in the NMS, and verbal autopsy interviews were arranged with the caregivers who had been with them before death. The 2016 WHO verbal autopsy tool was adapted for the specific study context and translated into Somali. Adaptations included making the tool shorter by removing questions not required for determining the causes of child death, correcting skip patterns, and simplifying language to enable use by

	Children (n=3898)
Sex	
Female	1999 (51·3%)
Male	1899 (48·7%)
Deaths recorded	
Total	153 (3·9%)
Male	67 (1·7%)
Female	86 (2·2%)
Verbal autopsies completed	
Total*	129 (84·3%)
Male	58 (86·6%)
Female	71 (82·6%)

Data are n (%). *The caregiver of one deceased boy refused to participate, the result of one verbal autopsy for a deceased girl was indeterminate, there was one data loss, and the respondents for 22 deceased children could not be traced. The indeterminate interview was regarded as a completed verbal autopsy.

Table 1: **Child deaths and verbal autopsy interviews completed between March, 2016, and March, 2018**

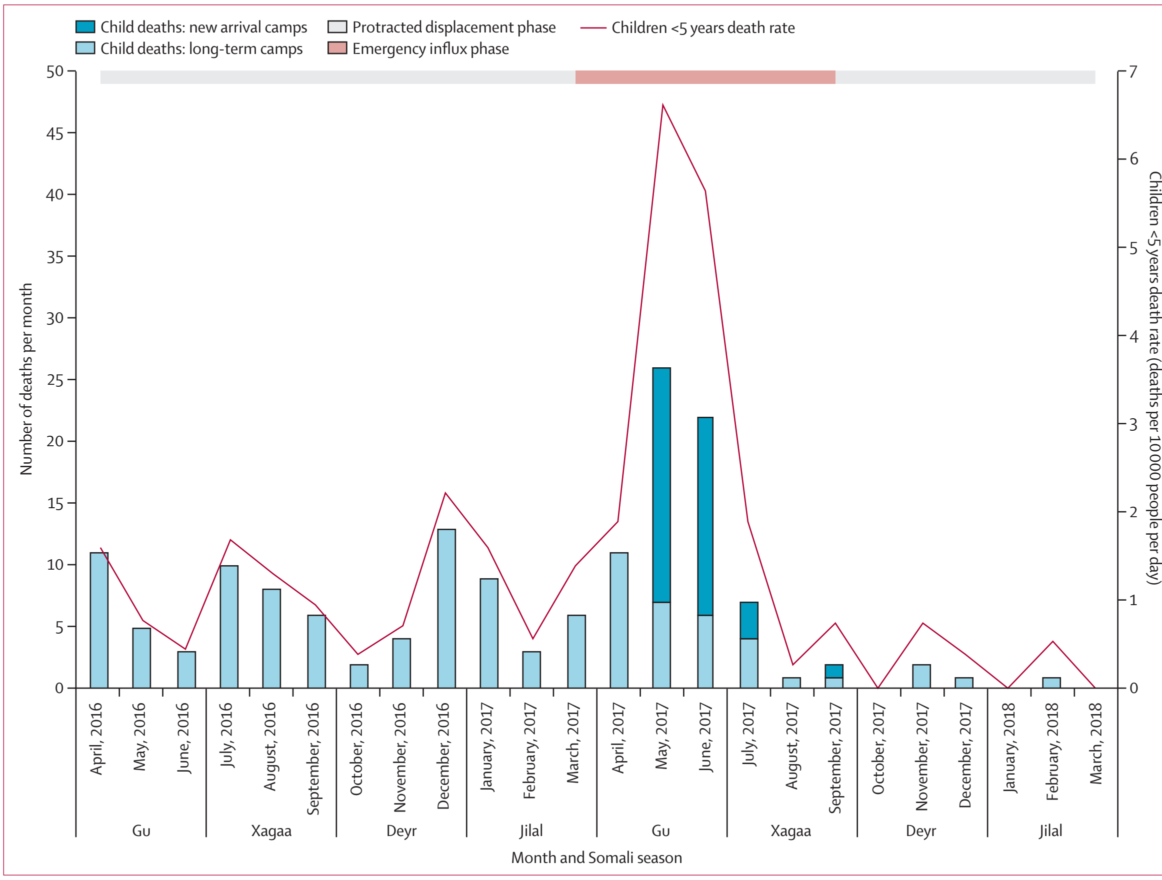

Figure 1: **Deaths among children aged 5 years and younger in the camps under surveillance**

interviewers who were not practising clinicians. Other adaptations included the addition of explosions as an indicator. The resulting verbal autopsy data collection tool was pilot tested, before study data collection, with seven deaths of children that occurred in two camps that were not included in the NMS. Only deaths that occurred after arrival and registration of households by the NMS teams were included. Deaths that occurred before registration or on the way to the IDP camps were excluded.

Verbal autopsy interviews were done by two trained nutrition supervisors as soon as possible after a minimum 2-week mourning period—an appropriate period for mourning as determined through consultation with the community and community leaders and considering the high mobility of IDP communities. Both nutrition supervisors that did verbal autopsy interviews were from Mogadishu, had bachelor's degrees in health sciences, and had good knowledge of the culture and the language spoken by the IDP. They underwent a 1-week training course on the verbal autopsy questions, interview techniques, counselling methods, and the use of Open Data Kit software. Appointments were made with verbal autopsy respondents and, if they were not available at the specified time, follow-up appointments were organised. All data were checked for completeness and consistency by the study coordinator and any issues were referred back to the field team for resolution. The probable causes of death were not fed back to family members because of local contextual and security issues.

For **Open Data Kit** see https://opendatakit.org

For **InterVa** see www.interva.net

To investigate the relationship between seasonality and mortality, we obtained rainfall data from the Somalia Water and Land Information Management, for weather stations in southern Somalia. The location of the stations and distances to the participating IDP camps were identified using Google Earth Pro. To calculate the regional average monthly rainfall, we used data from weather stations that were within 250 km of the IDP camps and had complete data records for the study period.

Outcomes

The primary outcome was cause of death as determined by verbal autopsy interviews with the caregivers of deceased children. Secondary outcomes were crude mortality, mortality of children younger than 5 years, nutrition, health, and vaccination status of the children and regional rainfall patterns.

Statistical analysis

We analysed verbal autopsy data using InterVA (version 5.1), which applies Bayesian reasoning to

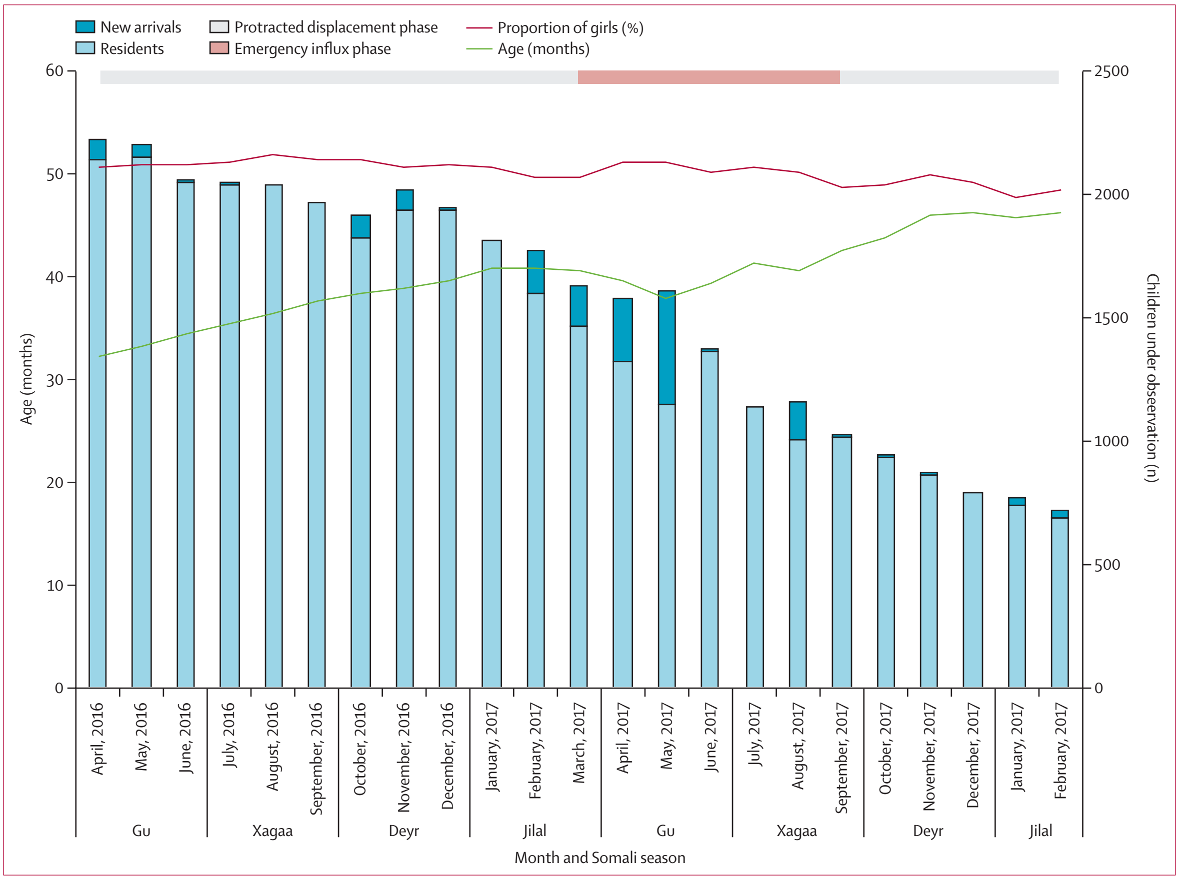

Figure 2: **Characteristics of the population under surveillance by month**

calculate the probability of cause of death categories using the reported presence of signs, symptoms, and the circumstances of death.[22] InterVA works by applying an expert defined probability matrix for a particular cause of death and calculates the probability of a specified list of causes of death. InterVA requires population HIV and malaria prevalence to be specified so that the model can account for baseline differences between locations.[23] Based on local expert knowledge, malaria prevalence was set as high and HIV set as low for the study context.

InterVA reports the probability of up to three of the most likely causes for each death. Using Microsoft Excel 2016, we summed the likelihoods of each cause from every individual death to estimate the burden of each cause at the population level. Dividing this estimate by the total number of deaths provided population cause-specific mortality fractions (CSMFs). The CSMF for the unknown category was calculated as the sum of the cases lost to follow-up plus the indeterminate proportion of the CSMF in cases that had a complete verbal autopsy interview.

Calculation of mortality rates and associations between causes of death and demographic data were done using Stata (version 15.1). *t* tests and χ^2 tests were used to test for differences in CSMF categories and the characteristics of deceased and surviving children.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

3898 children were followed up during the study and contributed 34746 person-months of observation time. 153 deaths were recorded by the surveillance system between March, 2016, and March, 2018 (table 1). The monthly variations in the death count and death rate among children aged 5 years and younger are shown in figure 1. The pattern of mortality during the first year of surveillance showed a periodicity similar to the regional rainfall patterns during the same period, peaks in rainfall preceding peaks in mortality by about 2 months (appendix).

See Online for appendix

From about March until July, 2017, the area was affected by an emergency influx of IDP, because of the 2017 food and health crises. Half of the total deaths occurred during this period and the death rate among children aged

	Protracted displacement* (n=75)	Emergency influx† (n=78)	Combined (n=153)	p value‡
Diarrhoeal diseases	27%	25%	26%	0·78
Severe malnutrition	13%	5%	9%	0·072
Measles	10%	25%	18%	0·021
Malaria	9%	3%	6%	0·055
Acute respiratory infection including pneumonia	8%	9%	8%	0·79
Meningitis and encephalitis	4%	1%	3%	..
Other and unspecified infectious disease	4%	0	2%	..
Acute abdomen	4%	1%	2%	..
HIV/AIDS related death	3%	0	2%	..
Liver cirrhosis	1%	2%	2%	..
Sickle cell with crisis	1%	4%	3%	..
Pulmonary tuberculosis	0·5%	0	0·2%	..
Unknown (Indeterminate or loss to follow-up)§	15%	25%	20%	0·081

CSMF=cause-specific mortality fraction. *Data from March, 2016, to February, 2017, and October, 2017, to March, 2018. †Data from March to September, 2017. ‡To compare common causes of death between the protracted and emergency phases a *t* test was done for causes in which the CSMF in one of the phases was greater than 5%. §Seven cases were lost to follow-up in the protracted displacement phase and 16 cases during the emergency influx.

Table 2: **CSMF ranked by proportional contribution during the protracted displacement phase**

5 years or younger exceeded the extreme emergency threshold of four deaths per 10 000 children per day during May and June, 2017. Note that only deaths that occurred after arrival and registration of households by the NMS teams are included. Deaths that occurred before registration or en route to the IDP camps are excluded. Many such deaths were reported anecdotally, so the results presented here very likely provide an under estimate of the total child deaths that occurred within the participating households during the emergency phase.

A high proportion of the child deaths during the emergency phase occurred in five camps that were set up to accommodate the newly arriving IDP households (figure 1). There was no difference in the proportion of children who died in the different types of camp; however, the incidence rate was significantly higher in the new arrival camps than in the long-stay camps (4·5 *vs* 1·2 deaths per 10 000 per day; p<0·001).

The characteristics of the population under surveillance during the protracted displacement and emergency influx phases are summarised in figure 2. Although the sex ratio of the population remained relatively constant, average age increased over the 2 years from 32·3 months to 46·2 months as the initially recruited cohort aged. Average age decreased during periods of influx as younger children were recruited and entered the cohort. 3603 (92%) of 3928 children came from the regions of Lower Shabelle, Middle Shabelle, or Bay in southern Somalia, with 190 (5%) coming from other regions within Somalia, three from Yemen, and one from Kenya. Region of origin information was not available for 131 (3%) children. 1902 (48%) of 3928 children belonged to the Rahanwyn (Digil and Mirifle) clan and 1122 (29%) came from minority clans, with 764 (19%) coming from the other three major clans (Dir, Hawiye, or Darod; figure 2).

Of the 153 children who died, 129 (84%) of the caregivers completed a verbal autopsy interview (table 1). The duration of verbal autopsy interviews was 20–30 min. One interview resulted in the identification of no specific causes of death. Verbal autopsy interviews were not successfully concluded for 24 deaths (nine boys and 16 girls). There was one refusal, one data loss, and 22 caregivers or close family members could not be traced.

Overall, diarrhoeal diseases, severe malnutrition, and measles were the top three causes of death (table 2). No significant differences were seen between the proportion of cause-specific deaths in the protracted displacement and emergency influx phases. However, it is notable that the CSMF for measles increased from 10·4% to 24·9% between the phases. The unknown CSMF also increased markedly during the emergency influx phase, largely because of an increase in loss to follow-up.

The pattern of cause-specific mortality by month is shown in figure 3. There was a spike in measles fatalities, beginning in February, 2017, a month before the rapid influx of IDP into the area began. In response to the increase in measles cases, the point prevalence of measles infection and the coverage of measles vaccination was measured by monthly questionnaire from April, 2017. The case count and prevalence of measles infection peaked in May (6·9%, n=110) and declined rapidly afterwards. Vaccination coverage rose from 40·8% in May, 2017, to 90·4% in October, 2017.

The characteristics of children who died or survived are shown in table 3. Children who died were more likely to be malnourished and younger. 26% of all deaths occurred in the five camps for new arrivals that were opened in 2017. The average duration of camp residence before death was 139 days and did not vary between the phases of protracted displacement and emergency influx.

Discussion

In this study, a prospective mortality surveillance and verbal autopsy system was used to identify the number and causes of deaths among internally displaced children aged 5 years and younger, during periods of both stable protracted displacement and emergency influx. Surveillance systems are a standard tool in humanitarian public health research;[24] however, to the best of our knowledge, this study is the first in Somalia to use verbal autopsy to identify and compare the causes of death. The death rate among children aged 5 years or younger that we observed during protracted displacement was high and crossed the emergency threshold of two deaths per 10 000 people per day in December, 2016, and reached seven deaths per 10 000 people per day during the emergency influx in May, 2017.[25] The death rates reported here are lower than

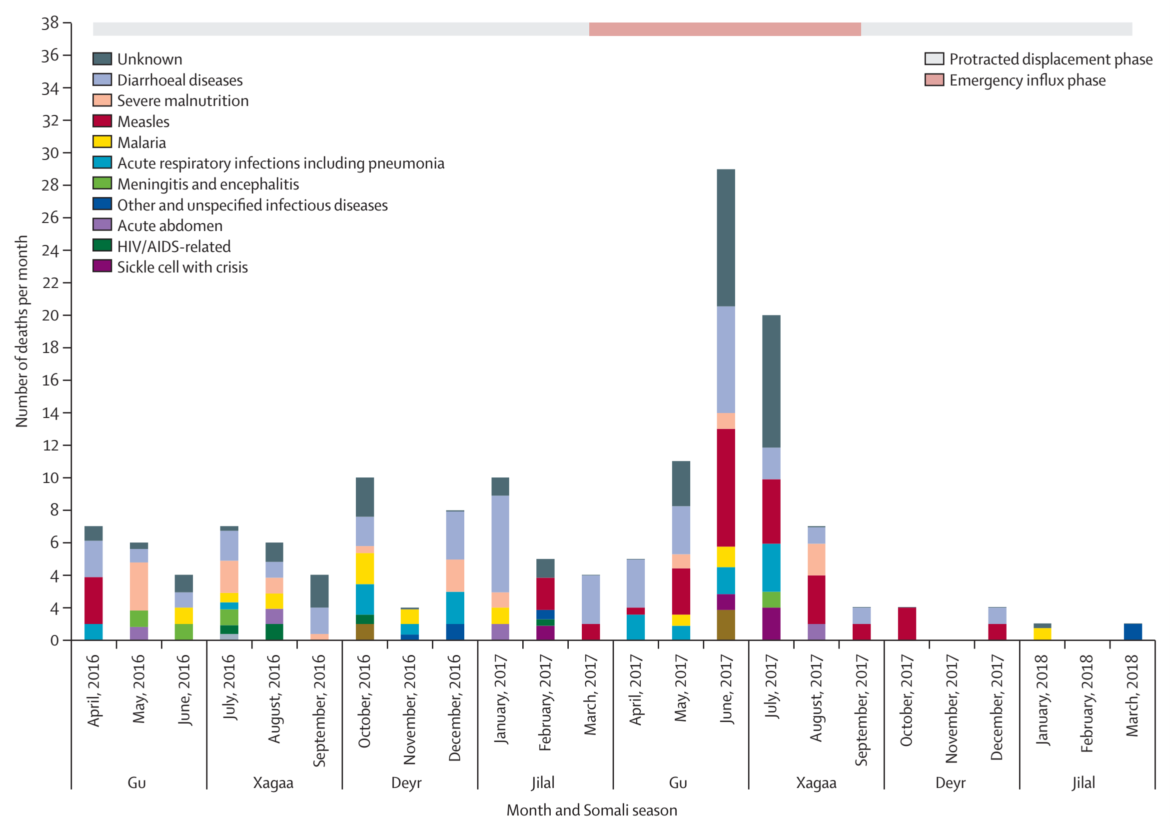

Figure 3: **Causes of death by month using caregiver reported dates of death**
Bars represent the contribution of each cause to the monthly death count, each cause will therefore not necessarily equal a whole number.[1]

those reported by population surveys during the 2011 famine, (10–15 deaths per 10 000 people per day) and much lower than during the 1992 famine, when it was estimated that 74% of internally displaced children aged younger than 5 years and living in camps in Afgooye died.[26,27] Nonetheless, the death rates reflect a serious humanitarian emergency.

Children who died were likely to be younger and have a lower MUAC than those who survived. Although non-significant, a higher proportion of deaths occurred in girls than in boys. However, caution should be applied in interpretation because many deaths were anecdotally reported to have occurred during the journey to Mogadishu throughout the distress migration that occurred in 2017 and these were not captured or recorded in this study. These reports are supported by the observation that the proportion of male children living in the camps for new arrivals was 46·7%, compared with 49·2% in the longer established camps. Boys are known to have a higher susceptibility to mortality, especially during emergencies, so it might be that the higher death count recorded in girls resident in the IDP camps is a result of the previous higher death rate among boys during the migration (ie, before they reached the camps and were enrolled in the surveillance system).[28]

In our study, the leading causes of deaths were diarrhoeal disease, measles, and severe malnutrition. Deaths from measles doubled during the emergency phase, presumably because of the low vaccination coverage in the population, high population density within the camps, and the very high prevalence of malnutrition.[29] The absence of a vaccinate-on-arrival policy for these IDP camps is also worth noting, which contrasts with the policy relating to emergency refugee operations.[30] It is important to note that the IDP camps in the study area are usually established on privately owned land and there is no single organisation that takes responsibility for the provision and coordination of services, although policy on vaccination and other health-care provision is set by the Ministry of Health in Mogadishu. For the 28 children who died with measles as the most likely cause, the mean time in the camps before death was 153 days, suggesting that a proportion of these infections took place within the camps and could have been prevented if good vaccination coverage had been achieved more rapidly.[31]

The most prominent causes of death observed in the emergency phase are in line with those reported in other emergency affected and displaced populations in Africa.[4,27,32] However, during the protracted displacement phase, cases with symptoms that could potentially be

	Deceased children* (n=153)	Survivors	p value
Mean age in months (95% CI)	22·9 (21·1–24·7)	38·6 (37·9–39·3)†	<0·001
Age categories			
6–23 months	90 (58·8%)	273 (17·0%)	<0·001
24–59 months	63 (41·2%)	1335 (83·0%)†	<0·001
Sex (95% CI)			
Male	45·8% (37·7–54·0)	48·8% (47·2–50·4)	0·47
Female	54·3% (43·9–64·3)	51·3% (47·7–54·9)†	0·48
Mean MUAC, cm (95% CI)	12·7 (12·3–13·0)‡	14·8 (14·7–15·0)†	<0·001
MUAC <11·5 cm (95% CI)	21·3% (14·5, 29·4)‡	3·1% (2·1–4·5)†	<0·001
Household size (95% CI)	5·7 (4·9–6·4)	5·8 (5·5–6·2)§	0·12
Mean duration of residence in camps before death, exit, or end of study period, days (95% CI)	139 (117–161)	280 (273–287)§	<0·001
Camp location			
Long-term camps	114 (74·5%)	2909 (77·7%)	..
New arrival camps	39 (25·5%)	836 (22·3%)	..
Combined	153	3745	0·36
Family type			
Single parent	26 (17·2%)	475 (14·0%)§	..
Monogamous	119 (78·8%)	2685 (79·3%)	..
Polygamous	6 (4·0%)	228 (6·7%)	..
Combined	151	3888	0·26

Data are n (%) unless otherwise stated. MUAC=mid-upper arm circumference. *Characteristics (ie, age, MUAC, and duration of residence) measured at the home visit in the month preceding death or at recruitment. †Average values for children, aged 6–59 months, present at the midpoint of the 2-year surveillance period (January–February, 2017; n=1608), excluding those who subsequently died. ‡127 children had a MUAC measurement available for the month preceding death. §Characteristics of all children recruited at age 6–59 months who survived during the surveillance period.

Table 3: **Characteristics of deceased and surviving children**

related to HIV/AIDS were, surprisingly common. This finding would potentially contrast with common assumptions about Somalia having a low prevalence of HIV/AIDS. It is important to note that the disease profile of the deceased is different from those who are alive and therefore, the fact that the data suggest that HIV/AIDS could be an important cause of death, does not necessarily mean that HIV/AIDS prevalence is high in the country.

Although it is well known that IDP are often a particularly vulnerable group in southern Somalia and similar contexts, studies have suggested that most IDP in Mogadishu are from marginalised clans or minority groups, which could further increase their vulnerability.[18,19] Our study finding is consistent with these data and shows that 95% of camp residents originated from the provinces of Lower Shabelle, Middle Shabelle, or Bay in southern Somalia and that 80% of the residents are from the Digil and Mirifle clans and minority groups.

We hypothesise that the periodicity in mortality that was observed during the first year of surveillance could be linked closely to seasonal rainfall patterns. An increase in morbidity during the Gu (April–June) and Deyr (October–December) rainy seasons has often been reported and, in this study, we found a peak in mortality associated with both the seasonal rains, with a 1–2 month lag between the peak rainfall and the increase in mortality.[33] This information suggests that seasonal peaks in mortality might be associated with higher transmission of infectious disease during the rainy seasons.

Use of health and nutrition surveillance systems in low income and emergencies settings have been reported in a number of studies.[34–37] The need to document mortality during crises has also been noted.[38] Despite the lack of technical consensus on the implementation of such surveillance systems they can still yield valuable month by month information to complement that obtained from much less frequent, intensive, nutrition survey exercises. The data collected for this study during the emergency influx were analysed on an ongoing basis and monthly reports were shared with organisations involved in the humanitarian response, including via the health and nutrition cluster coordination mechanisms.

This study was also important in quantifying the nature of migration and settling behaviour in the Afgooye corridor. We found that during a large influx, new arrivals are not integrated into pre-existing camps but tend to settle in newly established locations. After arrival, the duration of residence tends to be short with a substantial proportion leaving within the first 2 months after settling, even as other families arrive. This migration behaviour could offer benefits in terms of registering for humanitarian assistance and then being able to move to new locations to avoid the overcrowded and unhealthy environment of the camps. This rapid movement out of camps by new arrivals was seen to be particularly high in camps where the death rates were the highest.

Strengths of this study include the use of local community health workers as the front-line data collectors for the NMS, backed up by a strong supervision team. Use of digital data gathering using standard smart phones for administering the verbal autopsy questionnaire helped to streamline and speed up the interviewing process. Verbal autopsy interviews were done by two well trained and experienced, Somali speaking, female interviewers.

During crises, humanitarian agencies typically do rapid surveys to assess the needs of the population and rely on perceived causes of deaths. However, evidence suggesting agreement between informant perceived and verbal autopsy-derived causes of death for individuals is scarce, especially for children,[39] which highlights the importance of using standardised verbal autopsy questionnaires as done here. Use of the standard WHO verbal autopsy questionnaire, with minor adaptations to reflect the humanitarian context, and analysis with the widely used InterVA software also allows for maximum comparability with other studies.

Although the overall follow-up proportion was over 80%, a limitation of this study was the relatively high loss to follow-up (22%) during the emergency influx phase. Loss to follow-up was primarily due to a lot of population movement during the emergency phase, which is a common observation in IDP camps in this area and the increase of unknown CSMF values during this phase was mainly due to families moving out of the IDP camps before the verbal autopsy team could locate them to conduct the interview. This loss to follow-up might have resulted in deaths for some causes, such as measles, being underestimated during the emergency influx, when the measles outbreak was at its height. The rapid migratory movements of IDP in and out of the camps made documentation of population numbers and days of exposure less precise than it might have been in other contexts. Identification and follow-up of participants was also challenging as many people were illiterate, names had multiple transliterations in written English, and desperate beneficiaries might have registered for different assistance programmes using different names. These challenges were mitigated by using local community health workers and other staff from the local area who were familiar with the camps and could quickly learn to recognise new arrivals and population movements during their monthly house-to-house data collection rounds. We are confident that the deaths of children (age 6–59 months) that occurred following registration of households in the NMS were reliably captured; however, it should be noted that the overall mortality of the children during the emergency phase is probably higher than reported here. Many deaths were anecdotally reported to have occurred while the families were in transit to the camps or before the child was registered in the NMS; therefore, this period of distress migration might have involved a higher death rate than that experienced after arrival. Additionally, the NMS was designed to only capture data on children 6–59 months, so we are unable to determine the burden of mortality in children younger than 6 months. As a high proportion of deaths usually occur in this younger age group the overall death rate is likely to have been underestimated.

Verbal autopsy data can be analysed using a range of different analytical models and software, and these different analysis methods could result in calculation of different CSMF. In this study we chose to use only InterVA (version 5.1) and we acknowledge that different results could have been obtained if using other analysis software, such as SmartVA or InSilicoVA.

Our findings provide unique, contemporary information that can help to understand the causes of death and inform priorities to improve health and reduce mortality in humanitarian crisis. It also provides proof of concept for the use of verbal autopsy in humanitarian settings and efforts to scale up its use.

Studies that use the next generation of digital tools, such as MIVA (mobile InterVA) are warranted. Further work is also needed to analyse the risk factors for the high death rates we observed, both during the protracted and the emergency influx stages. This analysis should include the role of malnutrition and clan membership, and the unexpectedly high, potential, contribution of HIV/AIDS. An enhanced understanding of the migratory behaviour and transitory settlement patterns we measured is also important to ensure relief programmes are meeting needs in an optimal way.

Mortality surveillance combined with verbal autopsy can provide useful and timely evidence on the causes of death among children age younger than 5 years during humanitarian crisis, which can be used to inform response planning and monitor the effectiveness of interventions. New innovations, such as the use of digital data gathering tools to streamline the informatics pathway, have enhanced the feasibility of using verbal autopsy in humanitarian contexts. A population surveillance system that collects monthly data from a purposively sampled population is able to provide timely data on emerging health threats and monitor the effect of interventions in a timelier way than nutritional surveys. Findings from this study reiterate the importance of direct health, water, sanitation, and hygiene, and nutrition interventions, including measles vaccination and therapeutic feeding, to reduce excess mortality during crises.

Contributors

AJS, CSG-E, EF, and MJ conceived, planned, and oversaw the study. HM and RA organised and did the data collection. AJS and MJ did the analysis. All authors reviewed, commented on, and approved the final manuscript. AJS, MJ, and EF accessed and verified all the data in this study. The corresponding author had full access to all of the data and the final responsibility to submit for publication.

Declaration of interests

We declare no competing interests.

Data sharing

Because of the relatively small number of deaths reported in this paper and the small geographical area in which they occurred, reliable anonymisation of individual data is not possible. Data will therefore not be made publicly available. Enquiries about data access can be sent to the corresponding author at a.seal@ucl.ac.uk.

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For **SmartVA** see https://crvsgateway.info/SmartVA~547

For **InSilicoVA** see https://cran.r-project.org/web/packages/InSilicoVA/index.html

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