BMJ Global Health

Geographical distribution of the health crisis of war in the Tigray region of Ethiopia

Mulugeta Gebregziabher,[1] Fasika Amdeselassie,[2] Reiye Esayas,[2] Zerihun Abebe,[3] Hannah Silvia,[4] Abeba A Teklehaimanot,[4] Jeffrey E Korte,[4] John L Pearce,[4] James J Cochran[5]

To cite: Gebregziabher M, Amdeselassie F, Esayas R, *et al*. Geographical distribution of the health crisis of war in the Tigray region of Ethiopia. *BMJ Global Health* 2022;**7**:e008475. doi:10.1136/bmjgh-2022-008475

Handling editor Seye Abimbola

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bmjgh-2022-008475).

MG and FA are joint first authors.

Received 12 January 2022
Accepted 5 April 2022

For numbered affiliations see end of article.

Correspondence to
Mulugeta Gebregziabher; gebregz@musc.edu

ABSTRACT

War destroys health facilities and displaces health workers. It has a devastating impact on population health, especially in vulnerable populations. We assess the geographical distribution of the impact of war on healthcare delivery by comparing the pre-November 2020 and the November to June 2021 status of health facilities in the Tigray region of Ethiopia. Data were collected from February 2021 to June 2021, during an active civil war and an imposed communication blackout in Tigray. Primary data were collected and verified by multiple sources. Data include information on health facility type, geocoding and health facility status (fully functional (FF), partially functional (PF), not functional, no communication). Only 3.6% of all health facilities (n=1007), 13.5% of all hospitals and health centres (n=266), and none of the health posts (n=741), are functional. Destruction varies by geographic location; only 3.3% in Western, 3.3% in South Eastern, 6.5% in North Western, 8% in Central, 14.6% in Southern, 16% in Eastern and 78.6% in Mekelle are FF. Only 9.7% of health centres, 43.8% of general hospitals and 21.7% of primary hospitals are FF. None of the health facilities are operating at prewar level even when classified as FF or PF due to lack of power and water or essential devices looted or destroyed, while they still continue operating. The war in Tigray has clearly had a direct and devastating impact on healthcare delivery. Restoration of the destroyed health facilities needs to be a priority agenda of the international community.

WHAT IS ALREADY KNOWN ON THIS TOPIC?

⇒ Previous research has shown deleterious effects of war on health and healthcare delivery. Due to limited communication and reporting, the extent of the direct impact on healthcare delivery of the war in Tigray has not been well characterised at a granular level, including its geographic distribution.

WHAT THIS STUDY ADDS?

⇒ In this study, we made a granular assessment of the functional status of all healthcare facilities in Tigray. Comparison between the pre-November 2020 and November to June 2021 status of each health facility revealed the extent and severity of the devastation and the geographical differences thereof.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY?

⇒ The catastrophic impacts of war on health and healthcare delivery should make war a priority agenda in health policymaking. This prioritisation may lead to improved research and strategies for preventing war and mitigating its negative impacts.

INTRODUCTION

Tigray is the northernmost regional state in Ethiopia. Homeland of the Tigrayan, Irob and Kunama peoples, the region is bordered by the Amhara region to the south and southwest, the Afar region to the east and southeast, Eritrea to the north and Sudan to the west. Tigray is the fifth most populous region of Ethiopia. Three out of four Tigrayans live in rural areas.[1] Tigray's official language is Tigrinya, and the majority of the region's 7 million people[2] are primarily agriculturalists. Mekelle, the capital, is 485 miles from the federal capital Addis Ababa. Currently, the region has 7 administrative zones, 52 woredas (districts) (34 rural and 18 urban woredas) and 814 tabias (subdistricts which is the smallest administrative unit with an average population of 5000 or approximately 1000 households).

Tigray has a three-tiered primary health system.[3] The lowest tier is a health post (with at least two community health extension workers), typically serving people in the rural areas. A health post is generally staffed by two community health extension workers implementing the health extension programme, is the smallest health institution structure in the rural areas and is designed to serve one tabia or kebele (the smallest administrative unit in the region). The second lowest tier is the health centre, which serves five kebeles or five health posts, or approximately 15 000–25 000

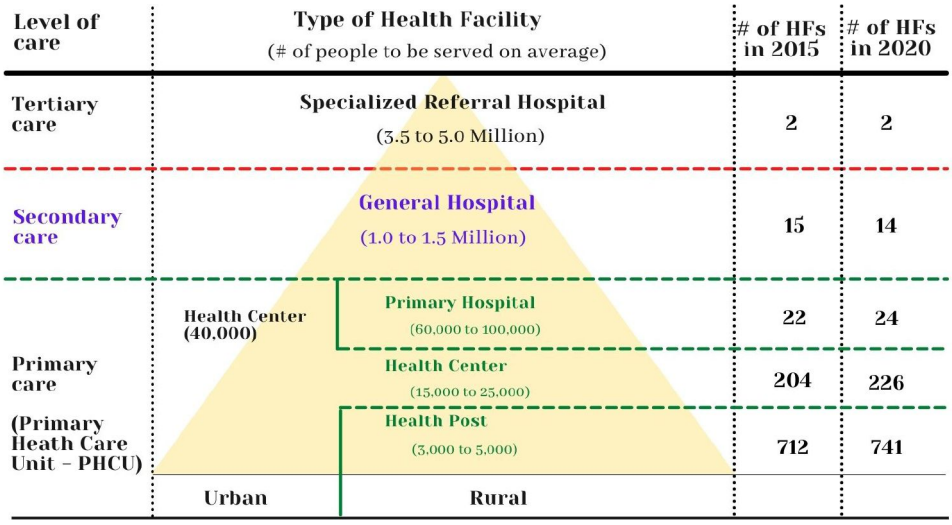


Figure 1 Structure of the Tigray Health Care System, which had three tiers: primary healthcare unit that includes health posts, health centres and primary hospitals; secondary care provided by general hospitals; and tertiary care provided by specialised referral hospitals. In 2015, there were 39 hospitals (2 referral, 15 general, 22 primary), 204 health centres and 712 health posts. As of November 2020, 40 hospitals (2 referral, 14 general, 24 primary), 226 health centres and 741 health posts.

rural or 40 000 urban residents. Hospitals have three tiers (primary, general and referral), which in turn provide healthcare services for those referred from health centres. Secondary care is provided by general hospitals, and tertiary care is provided by specialised referral hospitals. In 2015, the healthcare system included 39 hospitals (2 referral, 15 general, 22 primary), 204 health centres and 712 health posts. Figure 1 depicts the healthcare system in 2015 and 2020.[3] The latest data on the health facilities are reported on Tigray Region Health Bureau (TRHB)'s bulletin.[4]

Since early November of 2020, the Ethiopian Federal Government and the Tigray Regional Government have engaged in a series of clashes. This ongoing political conflict escalated dramatically on 4 November 2020, when Ethiopian Prime Minister Abiy Ahmed ordered a military offensive against regional forces in Tigray.[2] The origins of the conflict are complex, but what is incontestable is that Ethiopian National Defense Forces and allied Eritrean Defense Forces have wantonly decimated the region's healthcare system.[5]

This conflict has produced a growing humanitarian emergency, with heavy casualties and population movements both internally and externally. The crisis has spilt across borders into neighbouring regions; since 7 November 2020, over 63 000 refugees have fled to Sudan (a nation that is ill-prepared to accept or care for such an influx of refugees).[6 7] An estimated 9 million people within or near the Tigray region are currently at risk due to increasing confrontations of escalating size, over 100 000 children could suffer from severe acute malnutrition in the next 12 months in Tigray (a 1000% increase), and more than 100 trucks of humanitarian supplies are now needed on a daily basis.[6] All these catastrophic conditions in Tigray are compounded by the deliberate decimation of health facilities and attacks on healthcare and aid workers.[8]

According to Médecins Sans Frontières (MSF), Tigrayan healthcare facilities have been deliberately attacked to debilitate them, but Ethiopian authorities counter that most of the damaged Tigrayan health services have been restored.[9] In a limited survey assessment, MSF further reports[9–13] that 20% of the 106 Tigrayan health facilities that MSF teams visited from mid-December to early March had been occupied by armed soldiers, nearly 70% had been looted, more than 30% had been damaged, one facility was being used as an army base, and only 13% were functioning normally, MSF concludes that the damaged, looted facilities and resulting lack of medical staff means people in the region have very little access to healthcare.

The impact on women's health is also immense. According to a report by the UN Special Representative on Sexual Violence[14 15] and other humanitarian agencies, serious instances of sexual violence have been reported. These include a high number of rapes (including in Mekelle) characterised by inhumane acts and threats of imminent violence where individuals are forced to rape members of their own family and gang rapes by invading forces. Some women have also been forced by military elements to have sex in exchange for basic commodities. The increase in the demand for emergency contraception and testing for sexually transmitted infections (STIs) in some medical centres are indications of an increase in sexual violence in the conflict zones. The sexual violence against women and girls has also been reported in a number of refugee camps.[15] These reported incidences of rape and sexual violence, which result in both severe physical and emotional trauma, certainly increase the burden placed on Tigray's medical system.

The United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA) reports[16 17] that delivery of supplies into Tigray is running far below what is needed, humanitarian needs in the neighbouring Afar and Amhara regions are increasing substantially due to the spillover of the conflict and access to health services and water supplies has been dramatically reduced in part due to the loss of communications and electricity in rural parts of the region. Although over a 100 trucks of food, non-food items and fuel must enter Tigray everyday to sustain assistance, humanitarian access into Tigray remains restricted to one insecure road through the Afar region that is plagued with long delays and checkpoints.[16 17]

These factors, when combined with damage and looting of facilities and lack of medical staff, result in very little access to healthcare. Other horrific atrocities have also been reported.[18 19] WHO estimates that only 22% of health facilities are functional and some 78% of the hospitals in the region are not accessible. Unconfirmed, reports of a cholera outbreak began to emerge from Adwa Town, Central Zone. According to OCHA, there has been reports of increasing sexual violence and abuses as well as malnutrition. Ongoing research suggests that a continuation of the Tigray war may lead to another failed harvest in the next season and lead to even more widespread famine.[8 20 21] ReliefWeb reports that the conflict has already left 91% of the Tigray population in dire need of humanitarian assistance (more than a 500% increase relative to the preconflict period) with an estimated 350 000 people in the region suffering from an extreme lack of food with at least 150 hunger-related deaths recorded in Ofla district alone.[20 21]

While the civil war in Ethiopia has been ongoing for more than a year, there is scant data and reporting on the health crisis of the war. A recent paper[22] has reported the latest assessment and analysis of the impact of war on the health system of the Tigray region in Ethiopia. However, this study neither provides the geographical distribution of the crisis nor uses primary data at the local facility level. Our study fills these gaps by providing granular data for each of the health facilities in Tigray region of Ethiopia.

The catastrophic humanitarian and public health crises resulting from this war are predictable and are hardly unique to this conflict; indeed, the literature reviewed by Haar *et al*[23] provides ample evidence of research on the impact of attacks on healthcare in armed conflict. Needless to say, war (armed conflict) is one of the most relentless social determinants of health impacting health equity and well-being. War *always* brings devastating short-term and long-term impacts on population health, especially for vulnerable populations. This problem is exacerbated by the weak state of the health systems that is often present in conflict-affected states and the increasing number of individuals who are affected by these conflicts (an estimated one billion people worldwide are now affected by armed conflicts).

Public health aims to protect and promote the public's health, while war impedes, disrupts, damages and even prevents public health efforts around the globe. On the other hand, war is unquestionably one of the most devastating risk factors impacting health worldwide; it is frequently not included when risk factors for healthcare delivery are listed or studied. For example, it is not listed by the American Public Health Association in the 35 public health issues and topics.[24]

The main goal of the study is to describe the postconflict functional status and geographic distribution of the health facilities in Tigray using recently collected data on the operational state of healthcare facilities.

The secondary goal is to use the case of the war on Tigray as an opportunity to create awareness among researchers and public health professionals to work together to identify best practices to promote public health efforts in war-torn areas. Specifically, the predictable catastrophic humanitarian and public health crisis the war on Tigray has created must be communicated to the scientific community and the general public to ensure that the international community understands the direct impacts of the war on healthcare delivery and takes appropriate action to address the resulting crisis.

METHODS

The data used in this paper were collected from February 2021 to June 2021, during an active civil war and an imposed communication blackout in Tigray. Despite the communication blockade, with limited availability of e-mail and text communication (sometimes multiple times a day due to uncertainty of getting e-mail access the next day), we were able to triangulate the data to get a more accurate and verified data set. Our key collaborators who participated in the collection and verification of the data were Mekelle University College of Health Sciences, TRHB, Tigray Health Research Institute and the former Interim Government of Tigray (see online supplemental appendix). We used these different sources to obtain some of the incomplete data on latitude and longitude coordinates as well as status of health facilities as of June 2021.

Data collected

The data include information on zone, woreda, tabia, village, health facility type, health facility status (fully functional (FF), partially functional (PF), not functional (NF), no communication (NC)) and functional status (yes/no) and geocoded location for each health facility. Figure 2 shows a map of Tigray's administrative zones and the region's districts (woreda).

Two key variables for our analyses were the classification or type of facility (health centre, general hospital or primary hospital) and the status (FF, PF, NF and NC) of individual health facilities. The status of each health facility was determined based on the following criteria that were established by the interim Tigrayan

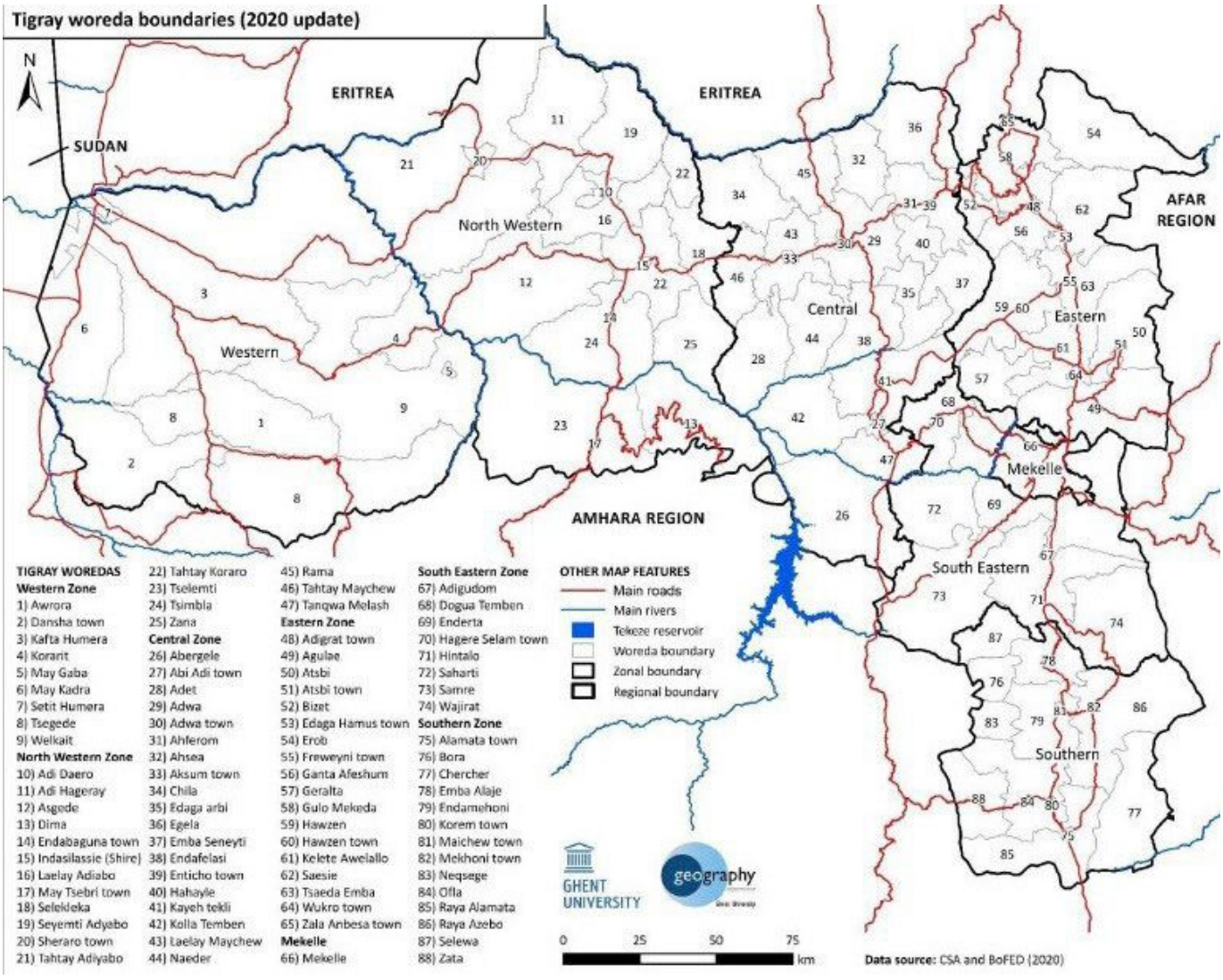


Figure 2 Map of the Tigray region of Ethiopia.

government. Status classification was provided to us with no detailed row data on the criteria used to determine the category of functional status:

A health facility is presumed to be **FF** if all of the following are fulfilled:

- Providing 24/7 emergency services
  - Emergency medical services
  - Surgical services (for hospitals and HCs with OR block)
  - Inpatient services (for hospitals)
  - Delivery service
  - Laboratory
  - Pharmacy.
- Available office hour OPD services.
- Reproductive, maternal, newborn and child health
  - Under five
  - ANC
  - Family planning
  - EPI.
- Communicable disease (TB, HIV, STI).
- Non-communicable diseases such as hypertension, DM, Mental Health (for hospitals).
- Adult OPD.
- Nutritional service
  - Screening
  - Therapeutic feeding.
- Functional management team, at least active CEO/health centre director.

A health facility is classified as **PF**;

- If one of the criteria for full functionality is absent
- If more than one criterion is absent and the reason for it is related to shortage of resources like human resource, medical product, safety or budget issues.

A health facility is classified as **NF**;

- If the facility is deserted.
- If the facility is occupied or being used for military purpose (whatsoever the level of damage/looting/service provision).
- If more than one criterion is absent and the reason for it is other than those relevant for partial functioning

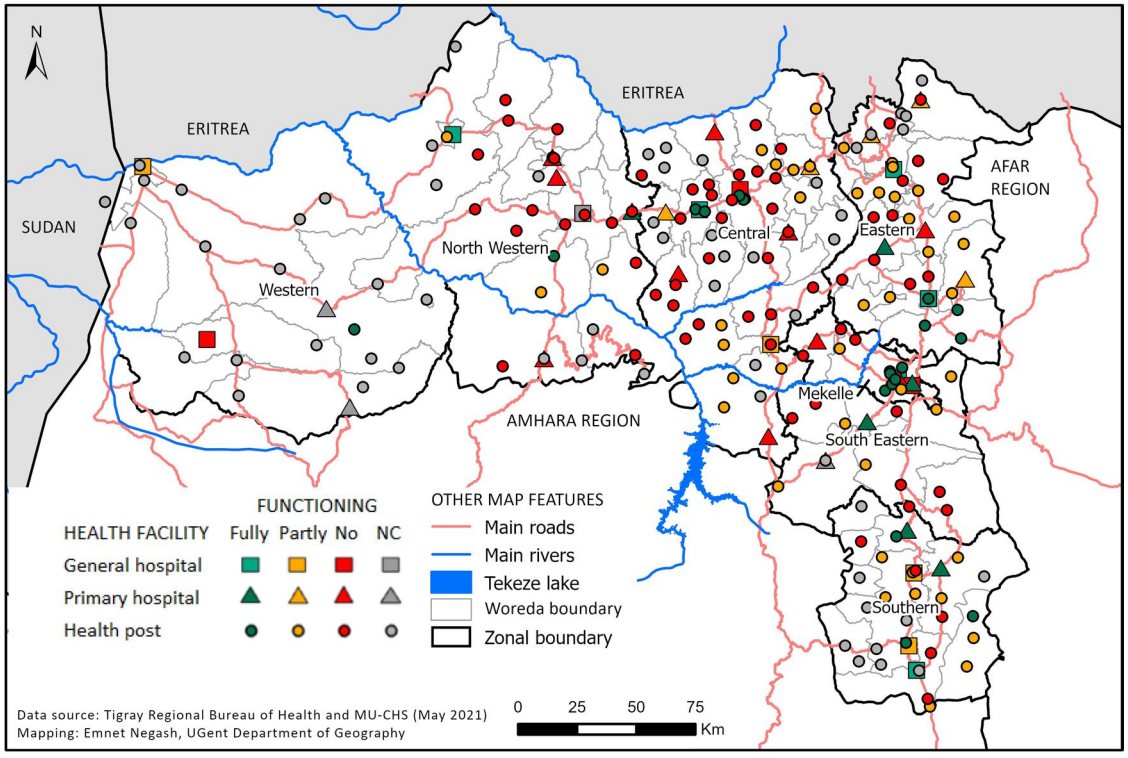


Figure 3 Geo-map of the status of health facilities in Tigray (as of June 2021). Due to sparseness of data (since there were only two referral hospitals with one in central and one in Mekelle), online supplemental appendix is based on combined count of referral and general hospitals labelled as general hospitals.

facilities such as structural damage, absence of basic amenities, etc.

- If the facility is completely looted/damaged and not able to function as a health facility.

A health facility is classified as NC if the facility is under occupation by Eritrean or Amhara forces.

Note that (1) these data represent a census of health centres, primary hospitals, general hospitals and referral hospitals in Tigray, (2) all of these facilities were FF prior to the outbreak of the war and (3) data on health posts were not collected because none is now functioning or there is NC due to occupation by other forces.

Statistical methodology

After data cleaning and verification, descriptive statistics were computed using MS Excel and R statistical software. We calculated frequencies and proportions for each variable by zone and aggregated at the region level. We used MS Excel to make bar plots. Due to sparseness of data (since there were only two referral hospitals with one in central and one in Mekelle), figure 3 is based on combined count of referral and general hospitals labelled as general hospitals. We also used the coordinate information for health facilities within Tigray to map the locations in conjunction with zone and village boundaries. This information was used to map the locations in conjunction with zone and woreda administrative features.

A colour-coded dot-density mapping with combination of symbols and colour codes were used to illustrate classification of these healthcare facilities and functioning status along with their spatial patterns. All geodatabase construction and mapping were done using ESRI's ArcGIS Pro software geographic information systems software where a static map is generated.

RESULTS

Recall that figure 1 depicts the structure of Tigray's healthcare system, which consists of three tiers: primary healthcare unit that includes health posts, health centres and primary hospitals; secondary care provided by general hospitals and tertiary care provided by specialised referral hospitals. As of November 2020, 40 hospitals (2 referral, 14 general, 24 primary), 226 health centres and 741 health posts.

Table 1 summarises the number of health facilities of each type by region (each of which was FF prior to the current war) in Tigray's healthcare system. We report the number of facilities with each status for Tigray overall and their geographical distribution by (Central Tigray, Eastern Tigray, Mekelle, Northwest Tigray, Southeast Tigray, Southern Tigray, and Western Tigray). This provides the baseline for our analysis of the impact of the conflict on the healthcare system of Tigray.

Table 2 shows the functional status of healthcare facilities (% of HF functioning) for each type of healthcare facility (referral hospital, general hospital, primary hospital, health centre, health post) of the whole Tigray region as of June 2021. We see that over 67.7% of health

Table 1 Number of health facilities of each type by regionfigures 2–6

Type	Central Tigray	Eastern Tigray	Mekelle	Northwest Tigray	Southeast Tigray	Southern Tigray	Western Tigray	Total Tigray
Health centre	61	39	11	40	22	32	21	226
General hospital	3	2	2	2	0	3	2	14
Primary hospital	6	5	2	4	3	2	2	24
Referral hospital	1	0	1	0	0	0	0	2
Zone totals	71	46	16	46	25	37	25	266

It summarises the number of health facilities of each type by region (each of which was fully functional prior to the current war). Due to sparseness of data (since there were only two referral hospitals with one in central and one in Mekelle), online supplemental appendix is based on combined count of referral and general hospitals labelled as general hospitals.

centres (153 out of 226) and over 56% of primary hospitals (13 out of 24) in Tigray were NF or not communicating. We also see that in only one category (referral hospitals) is as many as half the facilities in Tigray FF (one of two in this category are FF). Only 25% of all primary hospitals, 10% of all health centres and 0% of all health posts at this point in time were still FF. Overall, less than 4% of all healthcare facilities across Tigray were FF as of June 2021.

Table 3 shows the health facility status (% of HF functioning) by geography at the zonal level as of June 2021. The numbers for Central Tigray are alarming, particularly with regards to the complete lack of primary hospitals in the FF category, two out of six PF and the remainder NF. We also see that nearly 74% of health centres (45 of 61) were confirmed NF or not communicating in the Central Tigray zone, and one of the three general hospitals in this region was NF. In the East Tigray zone, only 10% of the health centres (4 of 39) were confirmed to be FF, and only one of the five primary hospitals was FF. Both of the general hospitals in Eastern Tigray remained FF.

Relative to other regions of Tigray, Mekelle has fared relatively well with 82% of the health centres, one of the two general hospitals, and the zone's only referral hospital confirmed remaining FF. However, note also that only one of the two primary hospitals in Mekelle was functional.

In the North West Tigray region, only 15% of health centres (6 of 40) were FF or PF, only one of the two general hospitals remained confirmable as FF, and only one of the four primary hospitals remained FF. In the South East Tigray region, less than half of health centres (9 of 22 PF and 0 of 22 FF) and only one of the three primary hospitals were confirmable as FF or PF.

In the South East Tigray zone, there were no general hospitals (a situation that existed prior to the onset of this war). Two of the three primary hospitals were confirmed NF or not communicating and none of the region's 22 health centres was FF (only nine are PF). In this region, only 4% (1 of 25) of all healthcare facilities remained FF.

In the South Tigray region, over one-third of health centres (12 out of 32) were confirmed as FF or PF, all of general hospitals were confirmed to be FF or PF, and all primary hospitals were FF. In the West Tigray region, less than 5% of health centres (1 out of 21) were FF or PF, and almost no health facilities were communicating; that is, over 95% of these facilities were under occupation by Eritrean or Amhara forces. A high proportion of health facilities in the South region has suffered similar fates. Regions in the northeast have suffered heavy damage; a high proportion of health facilities in these regions was either NF or PF. Only a very small proportion of health facilities across the entire Tigray region was FF. Additionally, only one of the two general hospitals in this region was at least PF, and neither of the two primary hospitals were communicating. Note that table 4 provides an aggregation of these results into two categories—FF and not FF—for the reader's convenience.

Figure 3 depicts a geo-map of the status of health facilities in Tigray (as of June 2021). The map shows

Table 2 Percentage and count of health facilities by status of health facilities (% of HF functioning as FF=fully functional, PF=partially functional, NF=not functional, NC=no communication) in the Whole of Tigray Region and Mekelle City of Tigray, in Ethiopia (as of June 2021)

	FF	PF	NF	NC	Total
Referral hospital	1 (50%)	1 (50%)	0	0	2
General hospital	6 (42.9%)	4 (28.6%)	3 (21.4%)	1 (7.1%)	14
Primary hospital	6 (25%)	5 (20.8%)	10 (41.7%)	3 (12.5%)	24
Health centre	23 (10.2%)	50 (22.1%)	78 (34.5%)	75 (33.2%)	226
Health post	0	0	0	741 (100%)	741
Total	36 (3.6%)	60 (6%)	91 (9%)	820 (81.4%)	1007

Table 3 Percentage and count of health facilities by status of health facilities (% of HF functioning as FF=fully functional, PF=partially functional, NF=not functional, NC=no communication) in the Tigray Region of Ethiopia by zone (as of June 2021)

Zone		FF	PF	NF	NC	Total
Central	Referral hospital	0	1 (100%)	0	0	1
	General hospital	1 (33.3%)	1 (33.3%)	1 (33.3%)	0	3
	Primary hospital	0	2 (33.3%)	4 (66.7%)	0	6
	Health centre	5 (8.2%)	11 (18%)	26 (42.6%)	19 (31.1%)	61
	Total	6 (8.5%)	15 (21.1%)	31 (43.7%)	19 (26.8%)	71
Eastern	Referral hospital	0	0	0	0	0
	General hospital	2 (100%)	0	0	0	2
	Primary hospital	1 (20%)	3 (60%)	1 (20%)	0	5
	Health centre	4 (10.3%)	14 (35.9%)	14 (35.9%)	7 (18%)	39
	Total	7 (15.2%)	17 (37.0%)	15 (32.6%)	7 (15.2%)	46
Mekelle	Referral hospital	1 (100%)	0	0	0	1
	General hospital	1 (50%)	0	1 (50%)	0	2
	Primary hospital	1 (50%)	0	1 (50%)	0	2
	Health centre	9 (81.8%)	2 (18.2%)	0	0	11
	Total	12 (75%)	2 (12.5%)	2 (12.5%)	0	16
North-West	Referral hospital	0	0	0	0	0
	General hospital	1 (50%)	0	0	1 (50%)	2
	Primary hospital	1 (25%)	0	3 (75%)	0	4
	Health centre	1 (2.5%)	5 (12.5%)	21 (52.5%)	13 (32.5%)	40
	Total	3 (6.5%)	5 (10.9%)	24 (52.2%)	14 (30.4%)	46
South-East	Referral hospital	0	0	0	0	0
	General hospital	0	0	0	0	0
	Primary hospital	1 (33.3%)	0	1 (33.3%)	1 (33.3%)	3
	Health centre	0	9 (40.9%)	12 (54.6%)	1 (4.6%)	22
	Total	1 (4%)	9 (36%)	13 (52%)	2 (8%)	25
Southern	Referral hospital	0	0	0	0	0
	General hospital	1 (33.3%)	2 (66.7%)	0	0	3
	Health centre	3 (9.4%)	9 (28.1%)	5 (15.6%)	15 (46.9%)	32
	Primary hospital	2 (100%)	0	0	0	2
	Total	6 (16.2%)	11 (29.7%)	5 (13.5%)	15 (40.5%)	37
Western	Referral hospital	0	0	0	0	0
	General hospital	0	1 (50%)	1 (50%)	0	2
	Primary hospital	0	0	0	2 (100%)	2
	Health centre	1 (4.8%)	0	0	20 (95.2%)	21
	Total	1 (4%)	1 (4%)	1 (4%)	22 (88%)	25

the geographic distribution of the status of each health facility at the locations in conjunction with Zone and Village boundaries. Colour-coded dot-density mapping were used to illustrate spatial patterning of our features of interest. It is clear from the map that there are only very few health facilities that remained to be FF (note that even those may not be functioning at pre-Nov 2020 levels due to shortage of health workers, medical equipment and supplies).

DISCUSSION

The data as of June 2021 show that more than 96% of the 1007 health facilities in the Tigray region of Ethiopia did not meet criteria for a FF status. In fact, none of the health facilities is at their prewar (pre-November 2020) operational status due to shortage of health workers, medical equipment power, water and supplies. Consequently, the health work force, the non-clinical staff and the services provided by these facilities were inoperable and, hence,

Table 4 Percentage and count of health facilities by status of health facilities (% of HF functioning as yes=fully functional, no=otherwise) in the Tigray Region of Ethiopia by zone (as of June 2021)

Zone		Yes	No	Total
Central	Referral hospital	0	1 (100%)	1
	General hospital	1 (33.3%)	2 (66.7%)	3
	Primary hospital	0	6 (100%)	6
	Health centre	5 (8.2%)	56 (91.8%)	61
	Total	6 (8.5%)	65 (91.6%)	71
Eastern	Referral hospital	0	0	0
	General hospital	2 (100%)	0	2
	Primary hospital	1 (20%)	4 (80%)	5
	Health centre	4 (10.3%)	35 (89.7%)	39
	Total	7 (15.2%)	39 (84.8%)	46
Mekelle	Referral hospital	1 (100%)	0	1
	General hospital	1 (50%)	1 (50%)	2
	Primary hospital	1 (50%)	1 (50%)	2
	Health centre	9 (90.9%)	2 (9.1%)	11
	Total	12 (75%)	4 (25%)	16
North-West	Referral hospital	0	0	0
	General hospital	1 (50%)	1 (50%)	2
	Primary hospital	1 (25%)	3 (75%)	4
	Health centre	1 (2.5%)	39 (97.5%)	40
	Total	3	43	46
South-East	Referral hospital	0	0	0
	General hospital	0	0	0
	Primary hospital	1 (33.3%)	2 (66.7%)	3
	Health centre	0	22 (100%)	22
	Total	1 (4%)	24 (96%)	25
Southern	Referral hospital	0	0	0
	General hospital	1 (25%)	2 (75%)	3
	Primary Hospital	2 (100%)	0	2
	Health centre	3 (9.38%)	29 (90.63%)	32
	Total	6 (19.4%)	31 (83.8%)	37
Western	Referral hospital	0	0	0
	General hospital	0	2 (100%)	2
	Primary hospital	0	2 (100%)	2
	Health centre	1 (4.76%)	20 (95.24%)	21
	Total	1 (4%)	24 (96%)	25
Total	Referral hospital	1 (50%)	1 (50%)	2
	General hospital	6 (42.9%)	8 (57.1%)	14
	Primary hospital	6 (25%)	18 (75%)	24
	Health centre	23 (10.2%)	203 (89.8%)	226
	Total	36 (13.5%)	230 (86.5%)	266

not providing any type of healthcare. The ongoing war has clearly had a direct impact on the healthcare delivery of the Tigray region. The implication of the destruction of health facilities varies by geographic location at the zonal (district) level. Almost all zones are heavily affected, with only 4% FF in Western, 4% FF in South Eastern, 6.5% FF in North Western, 8.45% FF in Central, 16.22% FF in Southern and 15.22% in Eastern. It is important to

reiterate that the data were collected from February to June 2021 in the Tigray region. The functionality of the health facilities is expected to be much worse at the date of publication of this report since there is a continued blackout and siege since June 2021 that led to extreme lack of medical and humanitarian aid.

The data we have presented serve as strong evidence of the rapid decimation of the Tigrayan healthcare system, of which only a small fraction of facilities remains fully or even somewhat functional. The data also show the frequency with which Tigrayan healthcare facilities have been overrun and are now under occupation by Eritrean or Amhara forces.

What makes all this devastating is the fact that the health infrastructure in Ethiopia is among the least developed, though the Tigray health infrastructure has made some significant strides since 1991. Ethiopia has fewer than one doctor for every 36 000 people—less than neighbouring Kenya, which has one doctor per 16 000 people. The devastation of the limited health infrastructure in Tigray coupled with the expected dire need for healthcare[14 15] will likely result in catastrophe unless a timely intervention and humanitarian aid are in place.

Although this is a single data point, from the impact of war on Tigray's health system, the phenomenon is common in regions afflicted by armed aggression. Thus, these results underscore our earlier assertion that war should be considered a priority health agenda and studied as a risk factor for healthcare delivery. Furthermore, as suggested by Bertone *et al*, decisions made in the immediate postconflict period may allow for the opening of a political 'window of opportunity' for reform of a war-decimated healthcare system.[25]

Hafner and Shiffman suggest that we have entered a period in which many organisations involved in global health direct much of their attention and resources to efforts intended to strengthen health systems.[26] If their conjecture is accurate, we may be at a juncture in which considering war as a public health crisis and designing healthcare systems to be more resilient to the impact of war aligns naturally with the objectives of these organisations.

The level of the human catastrophe is exacerbated by the confluence of the destruction of health facilities and blockade of humanitarian aid to the Tigray region.[27 28] According to the Associated Press[27] and other UN reports, there is clear evidence that deaths due to starvation have occurred in Tigray since Ethiopia's government imposed what the United Nations refers to as 'a de facto humanitarian aid blockade' in June.[28] Moreover, according to 3 October 2021 press release and BBC interview by the Health Bureau head of the Tigray region, the Tigray health system is under the risk of collapse with more than one million children under 5 years old at risk of imminent death, 22 000 health workers displaced, more than 37 health workers killed and 78 health workers injured.[28–30]

The results of this study show that war has negative effects on most of the identified factors affecting health and development of environments for healthy living; previously operational healthcare systems are far less available after the onset of war. Although additional studies are needed to explore and clearly document data related to these effects, it is clear that healthcare systems and their providers are essential to address the negative health effects of war and postwar health issues.

Some of the defining characteristics of the armed conflict that has been raging in Tigray include total blockade of humanitarian aid, wanton destruction of health facilities and the displacement of millions of people.[31 32] These weaponised actions have exposed thousands of civilians facing man-made starvation and millions more with acute food insecurity due to the Ethiopian government's refusal to allow the necessary humanitarian aid to enter the country in sufficient quantity, thus creating a famine crisis of unprecedented proportions.[33 34] As reported in a recent publication,[35] the magnitude of the severe acute malnutrition problem is alarming even with figures that are reported to be known an underestimate of the situation due to the limited assessment feasible under the armed conflict and blockade circumstances.

The key limitations of the study are the fact that the data were collected under total blockade and under the shadows of the civil war in Tigray. It is also limited to data collected from the limited geography of the Tigray regional state recognised by the Federal Republic of Ethiopia until June 2021. It is well known that, during civil war, collection and objective assessment data on health are challenging.[36 37] In addition to the interest by parties involved in conflict to try to use data and statistics for their political gain, the lack of access to insecure areas is an impediment to the collection of high-quality data. However, all possible mitigation factors including triangulating data from multiple sources (listed above) were used to make sure that the collected data are of high quality. We have also included a team of local, national and international experts to make sure that the analysis and write up reflect the data we collected. There are some developments since June 2021, but the security situation and the continued blockade and black out continue to make collecting additional data challenging.

Little research has been done to clearly document the effects of war on the social determinants of health[38] and the sustainable development goals influencing health (13 of the 17) that have been identified by the United Nations and the WHO[39]; this is likely due to the difficulty in collecting reliable and meaningful data amidst an armed conflict. The collection and analysis of the data for this study may serve as an example for future studies and shape current US and UN policies towards resolving the current Tigrayan crisis and future crises.

Public health aims to protect and promote the public's health, while war impedes, disrupts, damages and even prevents public health efforts around the globe. Thus, global health associations should list war as a priority health issue. This will encourage researchers to suggest prevention measures and public health professionals to

work together to identify best practices for promoting public and global health efforts in war-torn areas.

Author affiliations
[1]Public Health Sciences, Medical University of Southern Carolina, Charleston, South Carolina, USA
[2]College of Health Sciences, Ethiopia and Mekelle University, Mekelle, Tigray, Ethiopia
[3]College of Health Sciences, Mekelle University, Mekelle, Ethiopia
[4]Department of Public Health Sciences, Medical University of South Carolina, Charleston, South Carolina, USA
[5]Culverhouse College of Business, The University of Alabama, Tuscaloosa, Alabama, USA

Twitter Mulugeta Gebregziabher @ProfMulugeta

Acknowledgements We would like to thank the NGOS and local organizations that helped us with the collection of the data. We would like to thank the colleagues at Mekelle University College of Health Sciences, Tigray Region Health Bureau (TRHB), Tigray Health Research Institute (especially Dr. Tewolde Wubayehu) and some experts in the TRHB of the Ex Interim Government of Tigray for their support during the collection and verification of the data. We would also like to thank Dr. Jan Nyssen and Mr. Emnet Negash for their help with the mapping. We also thanks the two anonymous reviewers and the BMJ-editorial staff for their important feedback.

Contributors MG conceived the idea. MG and FA designed the study. MG, FA, RE, ZA collected the data, MG, HS, JLP, AAT, JJC analysed the data, MG and JJC drafted the manuscript. All authors critically reviewed and approved the manuscript. *MG, FA, RE, AAT verified the underlying data.

Funding This project was supported by a grant to Dr. Gebregziabher (PI) and Dr. Korte (Co-I) from the Medical University of South Carolina (MUSC) Center for Global Health. In addition, Dr. Korte received support from the National Center for Advancing Translational Sciences of the National Institutes of Health under Grant Number UL1 TR001450. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health or MUSC or UA.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The ethical approval of the project was made by the IRB of Mekelle University, which classified it as Not Human Subject Research and, as such, not subjected to IRB oversight.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information.

Author note Please see the reflexivity statement in an online supplemental file 1.

REFERENCES

1 RST. Regional state of Tigray, socio-economic baseline survey report of Tigray regional state, nov. 2018, PP. 6 and 24, 2018
2 Neuman S. 9 Things To Know About The Unfolding Crisis In Ethiopia's Tigray Region. NPR.org. Available: https://www.npr.org/2021/03/05/973624991/9-things-to-know-about-the-unfolding-crisis-in-ethiopias-tigray-region [Accessed March 5, 2021].
3 TRHB. *Tigray regional health bureau II ten years health Bulletin (EFY 1998-2007 or 2006/7-2014/5*. Mekele, Tigray, Ethiopia: Tigray Regional Health Bureau (TRHB), 2016.
4 TRHB. *Tigray health sector 2021 annual Bulletin*. Mekele, Tigray, Ethiopia: Tigray Regional Health Bureau (TRHB), 2022.
5 Rubenstein L, Gebregziabher M. The assault on health care in Tigray. The Hill. Available: https://thehill.com/opinion/international/567825-the-assault-on-health-care-in-tigray [Accessed August 14, 2021].
6 Ethiopia. Tigray region humanitarian update. Available: https://reports.unocha.org/en/country/ethiopia [Accessed August 20, 2021].
7 MSF. Ethiopia: update on the humanitarian situation and MSF response in Tigray. Available: https://www.msf.ie/article/ethiopia-update-humanitarian-situation-and-msf-response-tigray [Accessed Mar 12, 2021].
8 Devi S. Tigray atrocities compounded by lack of health care. *Lancet* 2021;397:1336.
9 MSF. Médecins sans Frontières. people left with few healthcare options in Tigray as facilities looted, destroyed: Médecins sans Frontières (MSF), 2021. Available: https://www.msf.org/health-facilities-targeted-tigray-region-ethiopia [Accessed cited April 4, 2021April 4, 2021].
10 MSF. Médecins sans Frontières. people in rural Tigray hit hard by conflict and neglect: Médecins sans Frontières 2021, 2021. Available: https://www.msf.org/ethiopia-people-rural-tigray-hit-impact-crisis-and-humanitarian-neglect [Accessed cited May 20, 2021].
11 MSF. People in Tigray, Ethiopia, are lacking medical care|MSF. *Médecins Sans Frontières (MSF) International* 2021 https://www.msf.org/people-tigray-ethiopia-are-lacking-medical-care
12 MSF. Médecins sans Frontières. people in rural Tigray hit hard by conflict and neglect: Médecins sans Frontières 2021, 2021. Available: https://www.msf.org/ethiopia-people-rural-tigray-hit-impact-crisis-and-humanitarian-neglect [Accessed May 20, 2021].
13 MSF. Médecins Sans Frontières. Ethiopia: "we never thought the conflict would hit us": Médecins Sans Frontières, 2021. Available: https://msf.org.au/article/project-news/ethiopia-we-never-thought-conflict-would-hit-us [Accessed cited May 20, 2021May 20, 2021].
14 UN-OCHA. Statement on Gender-Based Violence in Tigray region of Ethiopia. Statement on Gender-Based Violence in Tigray region of Ethiopia - Ethiopia | ReliefWeb [Accessed February 24, 2022].
15 Boezio G. Office of the special representative on sexual violence in conflict, 2021. New York. Available: https://www.un.org/sexualviolenceinconflict/press-release/united-nations-special-representative-of-the-secretary-general-on-sexual-violence-in-conflict-ms-pramila-patten-urges-all-parties-to-prohibit-the-use-of-sexual-violence-and-cease-hostilities-in-the/
16 UNOCHA. The UN Office for the Coordination of Humanitarian Affairs. Ethiopia - Tigray region humanitarian update situation report, 27 April 2021 - Ethiopia. *Relief Web*;2021 https://reliefweb.int/report/ethiopia/ethiopia-tigray-region-humanitarian-update-situation-report-27-april-2021
17 UNOCHA. The UN Office for the Coordination of Humanitarian Affairs. Ethiopia - Tigray Region Humanitarian Update. Available: https://reports.unocha.org/en/country/ethiopia/ [Accessed August 21, 2021].
18 World Vision Ethiopia. Tigray crisis response: Situation Report #7, 5 February 2021|ReliefWeb. Available: https://reliefweb.int/report/ethiopia/world-vision-ethiopia-tigray-crisis-response-situation-report-7-5-february-2021
19 Annys S, VandenBempt T, Negash E, *et al*. Tigray: atlas of the humanitarian situation in Tigray. Available: https://www.researchgate.net/publication/349824181_Tigray_Atlas_of_the_humanitarian_situation [Accessed February 24, 2022].
20 World Peace Foundation. Starving Tigray - How Armed Conflict and Mass Atrocities Have Destroyed an Ethiopian Region's Economy and Food System and Are Threatening Famine. Tufts university & World Peace Foundation Report. Available: https://sites.tufts.edu/wpf/starving-tigray/ [Accessed February 24, 2022].

21 UNHCR Protection Brief. Ethiopia: Tigray region - July 2021. Available: https://reliefweb.int/report/ethiopia/unhcr-protection-brief-ethiopia-tigray-region-july-2021 [Accessed August 21, 2021].
22 Gesesew H, Berhane K, Siraj ES, *et al*. The impact of war on the health system of the Tigray region in Ethiopia: an assessment. *BMJ Glob Health* 2021;6:e007328.
23 Haar RJ, Read R, Fast L, *et al*. Violence against healthcare in conflict: a systematic review of the literature and agenda for future research. *Confl Health* 2021;15:37.
24 American Public Health Association website,. Available: https://www.apha.org/topics-and-issues [Accessed July 28, 2021].
25 Bertone MP, Samai M, Edem-Hotah J, *et al*. A window of opportunity for reform in post-conflict settings? the case of human resources for health policies in Sierra Leone, 2002-2012. *Confl Health* 2014;8:11.
26 Hafner T, Shiffman J. The emergence of global attention to health systems strengthening. *Health Policy Plan* 2013;28:41–50.
27 Anna C. 'I just cry': Dying of hunger in Ethiopia's blockaded Tigray. Available: https://apnews.com/article/africa-united-nations-only-on-ap-famine-kenya-ef9fe79cc0cf35917fd190b6e9bd0f46?utm_source=Sailthru&utm_medium=email&utm_campaign=New%20Campaign&utm_term=Morning%20Wire%20Subscribers [Accessed September 20, 2021].
28 BBC. Ethiopia's Tigray crisis: Hospitals 'vandalized and looted. Bbc news. Available: https://www.bbc.com/news/world-africa-56399882 [Accessed Mar 15, 2021].
29 BBC. Ethiopia: un warns of aid crisis in Tigray. *BBC Sounds* https://www.bbc.co.uk/sounds/play/w172xxxql7lnqb9
30 BBC. Tigray crisis- if aid doesn't arrive immediately, the unfolding crisis will reach 1984 humanitarian crisis levels'. Interview with Dr Hagos Godefay, Head of Tigray Health Bureau. *BBC Tigrigna* 2021 https://www.bbc.com/tigrinya/news-58717095?at_campaign=64&at_custom1=%5Bpost+type%5D&at_custom2=facebook_page&at_medium=custom7&at_custom3=BBC+News+Tigrinya&at_custom4=B4087DBA-24DF-11EC-8763-0A1716F31EAE&fbclid=IwAR2QgtODJlzUdWBbFcfB9c5Mb3L8_HULrZ7h_Fr4HOtrxQ4nH0-bXnB-byw
31 UN. Catastrophe 'unfolding before our eyes' in Ethiopia's Tigray region – UN chief, 2021. UN news. Available: https://news.un.org/en/story/2021/08/1098582 [Accessed Oct 4, 2021].
32 Refugee International. Six tough questions we need to ask about the famine in Tigray, 2021. Available: https://www.refugeesinternational.org/reports/2021/8/19/6-tough-questions-we-need-to-ask-about-the-famine-in-tigray [Accessed Oct 4, 2021].
33 USAID. Latest Ethiopia fact sheet. Ethiopia-Northern Ethiopia crisis. Available: https://www.usaid.gov/humanitarian-assistance/ethiopia [Accessed 30 December 2021].
34 UNOCHA. Ethiopia - Tigray Region Humanitarian Update Situation Report. Available: https://reliefweb.int/report/ethiopia/ethiopia-tigray-region-humanitarian-update-situation-report-3-june-2021 [Accessed 3 June 2021].
35 Mulugeta A, Gebregziabher M. Saving children from man-made acute malnutrition in Tigray, Ethiopia: a call to action. *Lancet Glob Health* 2022;10:e469–70. Online ahead of print. PMID.
36 Checchi F, Warsame A, Treacy-Wong V, *et al*. Public health information in crisis-affected populations: a review of methods and their use for advocacy and action. *Lancet* 2017;390:2297–313.
37 Checchi F, Roberts L. Documenting mortality in crises: what keeps us from doing better. *PLoS Med* 2008;5:e146.
38 World Health Organization. A conceptual framework for action on the social determinants of health. A conceptual framework for action on the social determinants of health (who.int).
39 World Health Organization. Health in the SDG era. Available: https://www.who.int/health-topics/sustainable-development-goals#tab=tab_1 [Accessed September 9, 2021].

Appendix – Reflexivity Statement

1. How does this study address local research and policy priorities?

The data were collected to study the geographical distribution of the health crisis of war in the Tigray region of Ethiopia. Thus, the results and conclusions are directly relevant to local and international policy makers as they prioritize the funding of the rehabilitation and restoration of the destroyed health infrastructure and health work force in the region. The inclusion of local researcher in the team allows for accounting of the local perspective on the discussion of the results of the study.

2. How were local researchers involved in study design?

The local authors (FA, RE, ZA) are long term global health collaborators of the first author (MG). As described in the contributions section, the joint first author FA was involved on the design of the study, collection of data, IRB application and in the drafting and editing of the manuscript. All the other local collaborators (RE, ZA) were also involved in the triangulation efforts of the data.

3. How has funding been used to support the local research team?

While some funds from the grant to first author (MG) and co-author (JK) from the Medical University of South Carolina (MUSC) Center for Global Health and co-author (JC) discretionary funds are used to pay for publication fees, there was no direct support to the local research team. Up to this point in time, the prevailing war situation in the Tigray region of Ethiopia doesn't allow for transfer of any funds from the US to Tigray.

4. How are research staff who conducted data collection acknowledged?

We have acknowledged the contributions of the staff of our key collaborators who participated in the collection and verification of the data including staff (FA, RE, ZA) of Mekelle University College of Health Sciences (MU-CHS), Tigray Region Health Bureau (TRHB), Tigray Health Research Institute (THRI), and the former Interim Government of Tigray.

5. Do all members of the research partnership have access to study data?

All members of the partnership have access to data.

6. How was data used to develop analytical skills within the partnership?

The first author (MG) had long term partnerships with Mekelle university and the Tigray Health Bureau. In fact, the Medical University of South Carolina had a formal memorandum of understating (PI: Gebregziabher) with Mekelle university that allowed for partnership between the two institutions on global health research efforts, including research capacity development. While the team members who participated in this particular research were involved in the discussions of the analytic methods and discussion of the findings, the prevailing war situation in the Tigray region of Ethiopia didn't allow for direct involvement of the staff of our partners at Ayder hospital of Mekelle university in the efforts to develop analytic skills as a result of this work. When peace prevails, we would like to return to our joint capacity development efforts that includes analytic skills development.

7. How have research partners collaborated in interpreting study data?

The team members (FA, RE, ZA) were directly involved in the interpretation and discussions of the findings of the study.

8. How were research partners supported to develop writing skills?

The first author (MG) had long term partnerships with Mekelle university and the Tigray Health Bureau including a formal MOU to undertake research capacity development. The team members who participated in this particular research were senior physicians (FA, RE, ZA) who didn't need any training on writing skills. However, such endeavours had been opportunities to train junior researchers in research methods including writing skills. When peace prevails, we would like to return to our joint capacity development efforts that includes analytic skills development.

9. How will research products be shared to address local needs?

This consensus statement will be published as open access. We have developed a post-publication dissemination plan in consultation with the journal to distribute recommendations across a wide constituency. This will include engagement with research leaders in global health and other fields involved in international collaborations, with potential journal signatories based in both high-income countries and low- and middle-income countries; and with journalists, again both based in high-income countries and low- and middle-income countries. We will present our findings in conferences as well as local seminars.

10. How is the leadership, contribution and ownership of this work by LMIC researchers recognised within the authorship?

Author FA worked as part of the senior authorship team in developing this manuscript, and his contribution has been recognised as joint first author. We have two authors (RE, ZA) from LMIC who contributed to the research. The first author (MG) and co-author (AT) are also originally from LMIC though they currently work in the US. Thus, the authorship has a good balance of researchers based in LMIC and high-income countries.

11. **How have early career researchers across the partnership been included within the authorship team?**

We have included early career researchers (AT, HS) within the authorship team. They attended all the workshops, contributed to data management and evidence synthesis. We acknowledge that they are based in high-income countries.

12. How has gender balance been addressed within the authorship?

Five authors are male (MG, FA, RE, ZA, JK, JP, JC) and two authors are female (AT, HS)

13. How has the project contributed to training of LMIC researchers?

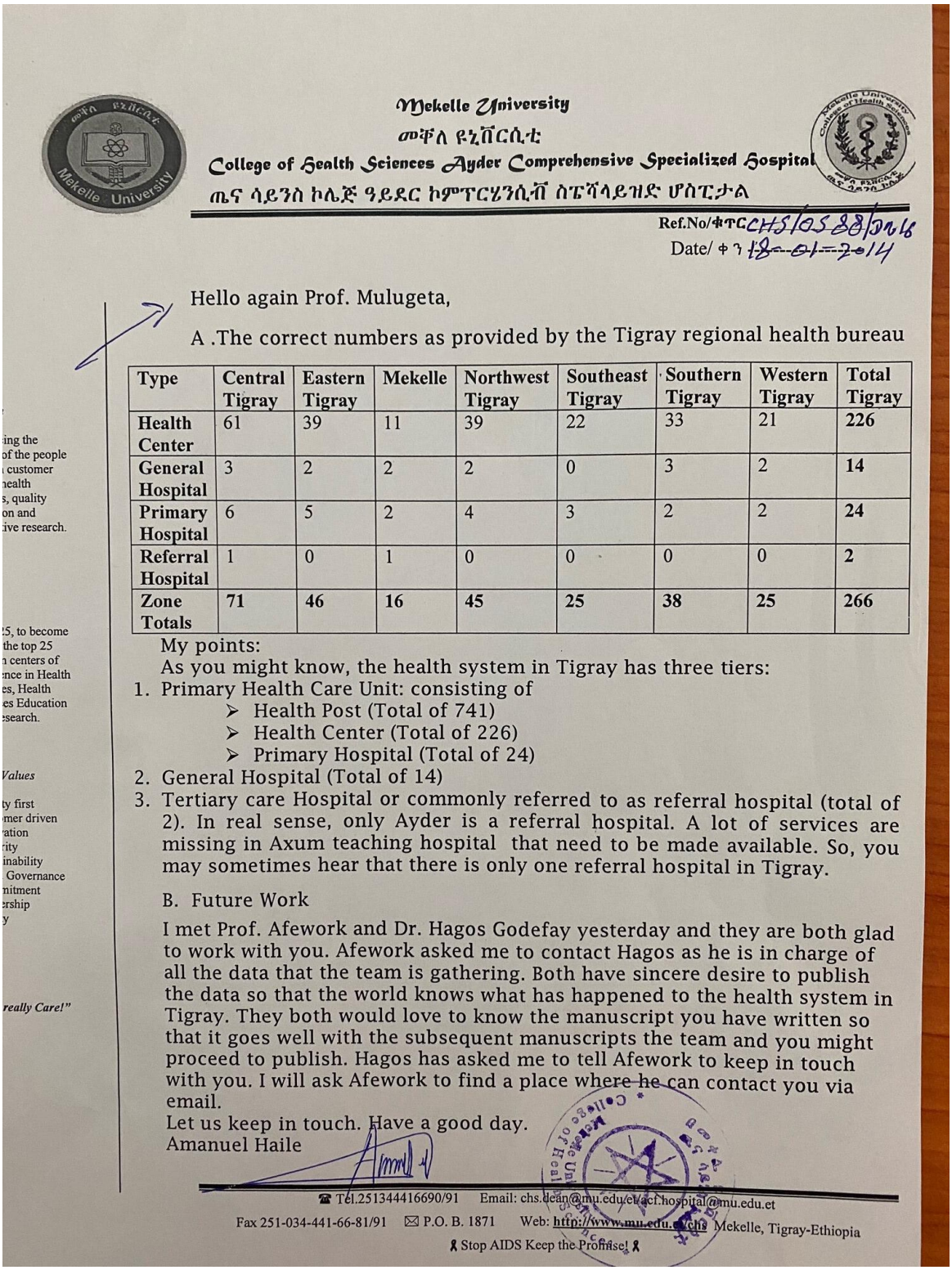
The authorship team is primarily composed of senior researchers except for two junior researchers who are not based in low- and middle-income countries. Thus, there was no need to do direct training of the LMIC researchers in the team.

14. How has the project contributed to improvements in local infrastructure?

This project has not directly contributed to improvements in local infrastructure.

15. What safeguarding procedures were used to protect local study participants and researchers?

There was no primary data collection on individual subjects as part of this project, therefore this question is not directly applicable. The data collection was on health facilities. We have specifically considered the issue of safeguarding within the manuscript.



Mekelle University
መቐለ ዩኒቨርሲቲ
College of Health Sciences Ayder Comprehensive Specialized Hospital
ጤና ሳይንስ ኮሌጅ ዓይደር ኮምፕርሂንሲቭ ስፔሻላይዝድ ሆስፒታል

Ref.No/ቁጥር CHS/025 88/2016
Date/ ቀን 18-01-2014

Hello again Prof. Mulugeta,

A .The correct numbers as provided by the Tigray regional health bureau

Type	Central Tigray	Eastern Tigray	Mekelle	Northwest Tigray	Southeast Tigray	Southern Tigray	Western Tigray	Total Tigray
Health Center	61	39	11	39	22	33	21	**226**
General Hospital	3	2	2	2	0	3	2	**14**
Primary Hospital	6	5	2	4	3	2	2	**24**
Referral Hospital	1	0	1	0	0	0	0	**2**
Zone Totals	**71**	**46**	**16**	**45**	**25**	**38**	**25**	**266**

My points:

As you might know, the health system in Tigray has three tiers:

1. Primary Health Care Unit: consisting of
   - Health Post (Total of 741)
   - Health Center (Total of 226)
   - Primary Hospital (Total of 24)
2. General Hospital (Total of 14)
3. Tertiary care Hospital or commonly referred to as referral hospital (total of 2). In real sense, only Ayder is a referral hospital. A lot of services are missing in Axum teaching hospital that need to be made available. So, you may sometimes hear that there is only one referral hospital in Tigray.

B. Future Work

I met Prof. Afework and Dr. Hagos Godefay yesterday and they are both glad to work with you. Afework asked me to contact Hagos as he is in charge of all the data that the team is gathering. Both have sincere desire to publish the data so that the world knows what has happened to the health system in Tigray. They both would love to know the manuscript you have written so that it goes well with the subsequent manuscripts the team and you might proceed to publish. Hagos has asked me to tell Afework to keep in touch with you. I will ask Afework to find a place where he can contact you via email.

Let us keep in touch. Have a good day.

Amanuel Haile

☎ Tel.251344416690/91 Email: chs.dean@mu.edu.et/acf.hospital@mu.edu.et
Fax 251-034-441-66-81/91 ✉ P.O. B. 1871 Web: http://www.mu.edu.et/chs Mekelle, Tigray-Ethiopia
Stop AIDS Keep the Promise!

Letter of approval and verification from the College of Health Sciences at Mekelle University, Tigray region of Ethiopiaa.