War-related Destruction of the Digital Health Data Infrastructure: Discovering Features for a Resilient Digital Health Information System

Maleda Taye, Araya Abrha Medhanyie & Mirjam Van Reisen

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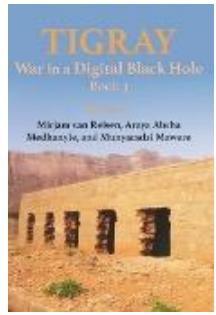

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https://raee.eu/wp-content/uploads/2024/10/Figures_Tigray.-War-in-a-Digital-Black-Hole-Volume-3-1.pdf

Contents

Chapter 12

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May a biased judge and a wounded cargo animal be perished.

Abstract

The consequences of the 2020–2022 war necessitate a transition to digital health systems in Tigray. Before the war, digital health transformation had already begun, spearheaded by the Tigray Regional Health Bureau. Significant investments had been made in improving not only digital information systems, but also paper-based health data systems to produce high-quality data for knowledge-based decision-making in health. During the war in Tigray the health data recording and reporting systems were destroyed. The collapse of the digital health system caused a critical transition, making a return to the original state unlikely without significant new conditions met. Hysteresis suggests that higher levels of support would be required for recovery. Therefore, instead of rebuilding the old system, it is recommended to develop new a digital health architecture suited to the current situation, incorporating lessons from past failures. This forward-thinking approach should focus on resilience, creating a robust digital health ecosystem that can withstand future disruptions, with a roadmap that includes local data management, local data ownership, and compliance with local regulations.

Keywords: Tigray way, health information system, digital health, Ethiopia, hysteresis, health resilience

Introduction

The destruction of health data is a major concern, alongside other damage to the digital health system, caused by and resulting from war and armed conflict. Armed conflict severely impacts the health system of countries, leading to the significant loss of health data (Debarre, 2018). Conflict disrupts the entire health sector, including the destruction of health infrastructure, which poses a challenge to accessing data from health facilities (Devkota & Van Teijlingen, 2010; Iqbal, 2019; Medhanyie *et al.*, 2024; Niguse *et al.*, 2024). Facility closures also interrupt record-keeping at health facilities (Gaffey *et al.*, 2020; Stocker & Medhanyie, 2024). Conflict can deteriorate the quality and completeness of health data, making it difficult to monitor disease outbreaks, track health trends, and develop effective healthcare policies (WHO, 2020). The trend of the crises in war-torn countries has similarities where the warring parties deliberately damage health facilities (Ekzayez *et al.*, 2021).

War undermines routines for health data collection, management, analysis, and dissemination in health information systems (HIS) (Dureab *et al.*, 2021). Many health institutions have been assaulted in conflict-affected nations over the last three decades, resulting in the destruction of hospitals and clinics as well as major losses of health data. Carolyn Briody *et al.* examined the facilities attacked during conflicts in Yemen (2015-Present), Syria (2011-Present), Iraq (2003-2011), Chechnya (1999-2000), Kosovo (1998-1999), and Bosnia and Herzegovina (1992-1995), focusing on the impact of violence on health data. A lack of health data could impede progress toward Sustainable Development Goal (SDG) 3 on health and well-being (Asi & Williams, 2018).

The use of health management information systems (HMIS) in Ethiopia has become central to the digital data revolution, transforming how health data are collected, analysed, and disseminated for decision-making (Health Sector Transformation Plan, 2015–2020). This progress extended to Tigray before the war, with significant improvements in electronic health systems (Advancing Partners & Communities, 2019). Tigray was at the forefront of implementing HIS, with substantial investments made by

the Tigray Regional Health Bureau since the reformed HMIS inception in 2015. The Bureau, guided by the Ethiopian Ministry of Health, structured the health information system, built capacity, and deployed digital systems over many years (FMOH, 2021a). However, this digital foundation of the health sector collapsed due to the war.

The war in Tigray started on 3 November 2020, and left health facilities deliberately looted, vandalized, and systematically destroyed (Fisaha, 2021, Niguse *et al.*, 2024; Medhanyie *et al.*, 2024, Stocker & Medhanyie, 2024). Medical equipment and computers were destroyed, patient files were damaged and scattered on floors and set on fire, and facilities were shelled. In addition, numerous healthcare workers were killed or forced to escape. The international medical humanitarian organisation Doctors Without Borders/Médecins Sans Frontières (MSF) shared the findings of an assessment by their team on 15 March 2021, exposing the deliberate and widespread destruction of health facilities across the Tigray region (MSF, 2021b). Stocker & Medhanyie (2024) listed a series of events in which the health system was negatively affected in the Tigray war and concluded that digital data on the health situation were missing. Stocker & Medhanyie (2024) also concluded that this health data was important for understanding the situation of health needs and prioritises needs for building back.

Hence, the research question is: *What were the cause of the destruction of the digital health system in the Tigray war, what features undermined the resilience of the system, and what are the requirements for rebuilding a resilient digital health data system?*

Methodology

The study was conducted as explorative participatory research with a case study in Adwa Hospital. It uses a deductive research approach.

Study area

This case study was conducted in Tigray, in northern Ethiopia. A case study was carried out in Adwa Hospital, which is in the central part of Tigray, about 240 km from Mekelle. Adwa is located in central Tigray and was on the front line for much of the war period. The

hospital suffered significant damage multiple times during the war and was subsequently converted into a military camp. As a result, it was unable to provide services for 8 months from November 2020 to June 2021.

Before the war, the facility had a daily turnout of 300 to 350 outpatients and a monthly turnout of 700 to 800 inpatients. The HIS implementation in Adwa Hospital was progressing well, and a large amount of health data had been recorded.

Study period and timeline

The study was conducted during 2020-2023. The war started on 3 November 2020 and a Cessation of Hostilities Agreement was signed on 2 November 2022 (ICHREE, 2023; Africa Union 2022). The following periods can be distinguished;

- Up to 3 November 2020 (pre-war): Tigray was administered by the regional government elected in Tigray.
- From 4 November 2020 to June 2021: Tigray was under the administration of an interim government appointed by the federal government.
- June 2021 to November 2022: The administration was appointed by the Tigray People's Liberation Front (TPLF).
- From November 2022 to March 2023 (post-war): Under Pretoria Cessation of Hostilities Agreement, Tigray was administered by the TPLF.

During the period 2020–2022 the Tigray region was under siege, which included the blocking of all electronic communication systems (Gebreslassie *et al.*, 2024). It was also under siege for other essential areas, such as banking and trade, which meant that digital equipment could not be obtained. The salaries of health workers, paid by the federal government of Ethiopia, were stopped during this period.

The research was conducted in the following periods:

- January-April 2022: preparations for the research and site visits
- May-June 2022: interviews and focus group discussions (FGD)

- July-September 2022: data analysis
- January 2023: Situation Report analysis

Some areas of Tigray continued to be under occupation during the period of research. Even after the Cessation of Hostilities Agreement was signed not all areas could be visited. The findings of this study pertain to the areas that were under the control of the regional administration, and which could be visited during the research period. This concerns primarily the central area of Tigray.

Data collection

The data collected for the study is qualitative data, with the following origin:

- Document analysis: The researcher conducted a mapping of the HIS in place in Tigray before the war.
- Literature review: A literature review was conducted to inventory the causes of health information disruption during the war.
- Analysis of Situation Report: A review based on the entries logged in the daily Situation Reports from December 2020 to June 2022 covering the situation in Tigray, prepared by Europe External Programme with Africa (EEPA) was carried out. A report of MSF on destruction of health facilities was also included.
- Observations: The researcher conducted observations during the period 2020–2022 and visited sites of health facilities.
- Key informant interviews with experts on HIS in Tigray: The study involved conducting interviews with three key informants at different positions in Adwa Hospital, including the Hospital Administrator (CEO), HMIS Administrator, and Health Information Technician.
- Focus group discussion on data production: a focus group discussion with one Health Information Administrator and 5 HMIS experts in the regional health bureau was conducted.

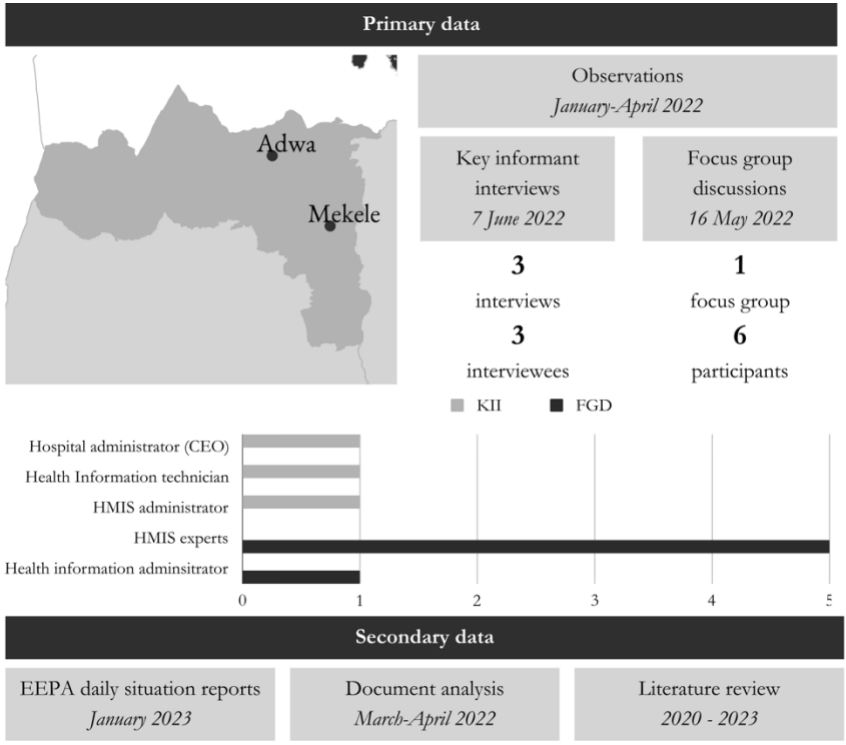

Figure 12.1. Overview of data collected and used in this study

The steps undertaken to conduct the research are listed below.

- Document analysis: The purpose was to obtain a baseline of the situation in Tigray before the war relating to (digital) health data information flows. An analysis of available policy tools and work formats in health data collection was conducted to identify good insight into the information flows and the different tools that were employed before the war.
- Literature review: The purpose was to investigate the causes for the loss of health information because of the war. Literature was reviewed based on the information contained on causes of information flow loss in the health sector during the war in Tigray.
- Analysis of Situation Reports: The purpose of the analysis of the entries in the Situation Reports was to obtain an objective verification of the findings obtained from the field visits with regard to the context of health facilities functioning during

the war. Documents were reviewed to substantiate the study and to better understand the situation before and during the war. A systematic review of the daily Situation Reports on the war in Tigray by Europe External Programme with Africa were included to support the study.

- Observations: The purpose of the site visits was to explore the situation on the ground. The researcher's observations during the period were written down in a research diary. On field visits notes and pictures were taken. Also, informal discussions were held with the health workers in the location. In this way, a detailed understanding of the situation in the field was obtained. Field visits were conducted in teams. The observations of the field visits were shared and discussed with other members of the team. The observations were also shared with the Regional Health Bureau which administered the situation of health services in the region and provided regular updates.
- Focus group discussions: The purpose of the focus group discussion was to verify critical points that had emerged from the observations during site visits. One semi-structured interview guide was developed for the focus group Discussion. The focus group discussion was conducted face-to-face. The focus group discussion was conducted in a physical meeting in the working room at Tigray Regional Health Bureau HMIS on 16 May 2022. A semi-structured interview guide was prepared with open-ended questions in English and the questions were translated into the local language Tigrinya. The discussion was conducted in the local language, Tigrinya. The discussion lasted for 2 hours and was audio-taped with a digital recorder.
- Interviews with resource persons: The purpose of the interviews was to receive an in-depth understanding of the salient issues that emerged from the field visits and to explore specific points which needed further understanding to complete the study. The selection of the participants was based on their proximity to the data production,

management, analysis, and reporting processes. The interviewees were experts at Adwa Hospital in the city of Adwa, which was a front city during the war. The investigator conducted face-to-face in-depth interviews individually in their private office at Adwa Hospital. The researcher received oral consent from all participants. A narrative approach with the guidelines of a topic list was used for in-depth interviews with resource persons with open-ended questions in English and translated into the local language Tigrinya. The interviews were carried out on the same day, on 7 June 2022, in a sequential order. The in-depth interviews were conducted for a duration of 30 minutes. The interviews were audio-taped with a digital recorder. Table 12.1. Overview of Study Methods

All personal data was anonymised and prepared to avoid identification. The following steps were undertaken to process and analyse the data obtained.

- Document analysis: The documents were analysed to obtain a listing of the HIS's used prior to the war; their purpose and the underlying information flow. The result was a baseline for the study in the form of a mapping of the situation on available health data information flows in Tigray that were in place prior to the outbreak of war.
- Literature review: A purposeful literature review was conducted from which an inventory of causes of the disruption of health information flows during war, was obtained.
- Situation Report analysis: The daily entries of the Situation Reports were included in an Excel sheet, relevant entries on health facilities were manually selected and through a coding-labelling qualities of the situation were manually logged, the entries were subsequently compared and analysed by the researcher. The analysis was conducted after the Cessation of Hostilities Agreement had been signed and access to all the Situation Reports could be obtained. The situation report analysis provided an independent source of information, in

addition to the fieldwork observations to triangulate the data obtained with regards to the status of the health facilities during the war.

- Observations: The observations on the use of the health system information systems during the war were logged in a research diary and discussed in the field visit teams, shared with other researchers upon return, and shared with the Regional Health Bureau for further verification and handling of information for the administration. The notes were consulted during the data analysis and provided important input in the topic list and questionnaire developed for interviews and the focus group meeting.
- Focus group: The focus group discussion was transcribed, translated and analysed using Microsoft Word 2019. Themes were identified by highlighting as many patterns as possible for each participant. The data were thematically analysed using back and forth review of the transcripts. The qualitative data analysis process has followed an inductive approach. The data were inductively coded against the employed conceptual framework focusing on the secondary consequences and the impacts on health data and HMIS.
- Interviews: An identical method was used as described in the preceding section. The data were coded against the themes identified in the focus group discussion. Where new themes emerged, these were marked and analysed.

Table 12.1. Overview of the research methodologies

Topic	Method	Time	Findings
Baseline on HIS	Document Analysis	March-April 2022	Inventory
Damage to health infrastructure	Literature review, site visits and Situation Report analysis	2020-2023	Hypotheses of causes, observations, verification and triangulation
Loss of healthcare workers and services at facilities, a decline in the quality and quantity of health data collected and interrupted experiences of using digital health systems	Site visits, focus group discussion, interviews, and Situation Report analysis	2022-2023	Observations, verification and triangulations
A lack of functioning of HIS	Focus group discussion and interviews	May-June 2022	Transcripts, coding labelling, identifying themes

Findings

The results of the study are presented in two parts. In the first part the results of the document analysis, literature review and the analysis of Situation Reports on the war in Tigray are presented. In the second part the experience by the users of the digital health systems is presented. These results are based on the focus group meeting and the interviews. The presentation of the experiences is also split in reported experiences from before the war, during the war and after the war.

Description of digital health systems before, during and after the war

Health data flows in Ethiopia

The data recording mechanism in most health facilities in Ethiopia is still manual, utilising papers and logbooks (Adane *et al.*, 2021). Health facilities would allocate large storage areas to keep records, which may complicate the management of patient records. Thus, the quality and safe storage of patient records determines the quality of healthcare service and delivery (Bisrat *et al.*, 2021). When record-keeping fails, medical errors occur, and this may hurt the services delivered to patients. Proper patient data recording and storage is the backbone of communication between healthcare providers. When patient data is lost or damaged, communication between healthcare providers breaks down, medical errors occur, and patients are put at risk (Taye, *et al.,* 2021).

The administration in the health sector of patient data is organised by the Ministry of Health at federal level in Ethiopia and the Regional Health Bureau. Ethiopia has a federal administrative structure with a certain devolved autonomy at the regional state level. The Regional Health Bureaus function horizontally under the regional government administration and report vertically to the Ministry of Health. In Tigray the Regional Health Bureau is part of the Tigray regional administration. During the war, a transitional government was put in place in Mekelle after the war broke out on 4 November 2020. The transitional regional government was later replaced by an administration that was put in place by the majority party in the region which lasted until 2023, when a new regional government was inaugurated, functioning under the Cessation of Hostilities Agreement, which was signed on 2 November 2022 (Africa Union, 2022).

The Ethiopian Ministry of Health, Regional Health Bureaux and other stakeholders were committed to realising the four transformation agendas of the first Health Sector Transformation Plans between 2015 and 2020 (FMOH, 2015). The Health Sector Transformation Plan is a five-year strategic plan detailing strategic

objectives and initiatives to ensure the health system provides excellence in health service delivery, quality improvement and assurance, leadership and governance, and health system capacity.

Table 12.2. Principle administrative units in the health sector

Ministry of Health	MoH	The Ministry of Health is a federal government ministry of Ethiopia, responsible for public health concerns.
Tigray Regional Health Bureau/ Regional Health Bureau	TRHB /RHB	is responsible for public health concerns at regional level.

The information revolution is an important element of the Health Sector Transformation Agenda. The information revolution aims at transforming the methodologies and mechanisms of capturing, storing, analysing, and disseminating patient health information (FMOH, 2016). As a result, some health facilities have started producing reliable and timely health data since the introduction of the information revolution roadmap guided by regional health bureaus administration at different levels of the health sector. This data production involves the standardization of data production processes, medical records, registries, tally sheets, and reporting formats (FMOH, 2021b). Following the period covering the first five years, a second Health Sector Transformation Plan was put in place, in 2020.

Digital health data programmes in Ethiopia

An inventory was made of software programmes utilised in the digital health information flows. The software systems are part of the digitization process going on under the leadership of the Ministry of Health and active engagement of national and international actors. These systems are designed to manage health data in the Ethiopian health sector (Lowenberg, 2020). This shows that a range of digital programmes are used in the sector for various purposes.

The systems in use in Ethiopia are:

- Electronic Community Health Information System (eCHIS)
- Electronic Medical Record (EMR)
- Health Management Information System (HMIS)
- District Health Information System2 (DHIS2)
- SmartCare
- Human Resource Information System
- Supply chain system
- Logistics Management Information Systems

An inventory set out in Table 12.3 shows different digital software systems that are relevant for the information flows in Ethiopia.

Table 12.3. Digital systems for production of health data in Ethiopia

Term	Definition
Electronic Community Health Information System	A mobile platform that assists in the management of health extension programmes through the collection and use of demographic data, health services delivery information and service utilisation.
Electronic Health Record	A digital version of a paper chart or register created and managed by health services providers at a health organisation to capture and store patient health information. Example is SmartCare which is fully functional at Ayder Hospital.
Health Management Information System	Collects, stores, analyses, and evaluates health-related data from health facility to district, regional and national administrative levels.
District Health Information System2	A system for HMIS aggregate data collection, analysis and reporting.

Term	Definition
SmartCare	(Electronic) Patient Records
Human Resource Information System	A software solution that maintains, manages, and processes detailed employee information and human resources-related policies and procedures.
Supply chain system	Interoperable systems for managing health system supply chain information in support of the Information Revolution (IR) agenda. There are different applications to support the supply chain system such as Dagu and mBrana.
Logistics Management Information Systems	The system of physical- and technology-based records and reports that supply chain workers and managers use to collect, organise, present and use logistics data gathered across all levels of the system.

With regards to data collection, the following categories of health support workers should be acknowledged within the digital health sector:

- Health extension workers: Staff of the Health Extension Program
- Health information technicians: A professional who is responsible for handling all technical aspects regarding managing patient health information.
- Members of the performance monitoring team (PMT): A multidisciplinary team which is primarily responsible for improving data quality and using information on a regular basis to evaluate the progress and to enhance healthcare delivery, is the main platform for routine data use in the health sector.

Digital health data information in Tigray (pre-war)

Before the war in Tigray, there were efforts to make a radical shift from traditional data use to systematic information use by the Tigray Regional Health Bureau. These efforts included initiatives such as the introduction of the HMIS, which involves a core set of indicators, standardized registers, patient cards, and reporting forms. The two platforms that were implemented to increase the utilisation of health data in Ethiopia are:

- DHIS2 at facility level
- eCHIS at community level

To avoid fragmentation, improve data quality, strengthen data analysis and use across all levels of the health sector, a web-based HMIS DHIS2 has been implemented since 2016. Ethiopia is one of the countries that adopted DHIS2 as its nationwide health information system platform (WHO, 2022). Almost all health facilities in Tigray were using DHIS2 when the war in Tigray began, and the facilities would send monthly, quarterly, bi-annual, and annual aggregate data to the district, Tigray Regional Health Bureau, and the Ministry of Health.

The Community Health Information System (CHIS) was implemented mainly using a unified data collection tool called the family folder. The family folder assists the management functions of health programmes, including the collection of data on basic demographic statistics, health service delivery, and utilisation based on the health extension package in health posts (Lowenberg, 2020). The eCHIS is a mobile platform implementation of CHIS, which was in the piloting phase just before the war started. The eCHIS was designed to collect health data at the community level within the Health Extension Programme (Ethiopia-Data Use Partnership, 2021). The Health Extension Programme is a national-level programme to create health equity by generating demand for essential health services through the provision of health information at the household level and access to services through referrals to health facilities.

The data collected using eCHIS would support health extension workers in their activities and empower decision-makers with high-quality data for improving the health system in implementing regions, one of which was Tigray.

Table 12.4. Inventory of paper-based and digital health data systems in Tigray before the war

System	Objective	Status in Nov 2020
DHIS2	Aggregate data produced in health facility and sent to Ministry of Health in Addis Abeba	Operational in most health facilities in Tigray
CHIS	Collection of data on basic demographic statistics, health service delivery, and utilisation based on the health extension package in health posts	Operational in most health facilities in Tigray
eCHIS	Digital mobile platform for CHIS	Pilot
Health Extension Programme	to create health equity by generating demand for essential health services through the provision of health information at the household level and access to services through referrals to health facilities.	Envisaged

System	Objective	Status in Nov 2020
Electronic Medical Record (EMR)	(Electronic) Patient Information Record System	Operational in Ayder Hospital in Tigray (e.g., SmartCare)

Disruption of digital health data flows due to Tigray war

The destruction of digital health data in Tigray caused by the war and its impact has not been given much emphasis during the preliminary damage assessments conducted by governmental and non-governmental organisations. A literature review was conducted to identify causes of disruption of information flows of health data within the situation of war.

In Tigray, the effects of the war on the health system resulted from the destruction through direct violence, forced displacement, other social crises, and the destruction and disruption of the health system (WHO, 2023). The war created a nearly total collapse of the healthcare system (Godefay, 2022).

The war disrupted both the operation of DHIS2, piloting of eCHIS, and all other digital health systems. The disruptions were caused by:

- Deliberate communication shutdowns during the siege implemented as part of the war (Yilma, 2021; Anthonio & Tackett, 2023)
- Power interruptions due to the destruction of infrastructure (Gebreslassie & Bahta, 2023)
- Computer damages due to destruction in the war (and lack of repair capability due to the siege)
- Displacement of healthcare professionals caused by the federal government (Gesesew *et al.*, 2021)

Increasing evidence pointed to most health facilities in Tigray being destroyed in the war. Table 12.5 shows information reported regarding the destruction of facilities in Tigray during the 2020-2022

war in the Situation Report of EEPA and by MSF. The reports are based on real-time observations during the war.

Table 12.5. Destruction of health facilities

Date	Facility	Location	Status	Reported by
26.12.2020	Hospitals	Wukro and Adigrat	Completely looted	EEPA, 2020, SR 37
31.12.2020	Health centres	Wukro, Negash, Idagahamus and Adigrat	Pictures show that medical equipment and pharmacies were completely destroyed and looted	EEPA, 2020, SR 42
07.01.2021	Hospital	Adwa	Looted	EEPA, 2021, SR 48
11.01.2021	Hospitals	Outside the capital city, Mekelle	Looted and many reportedly destroyed	EEPA, 2021, SR 52
29.01.2021	Health facilities	Between Mekelle and Aksum	Around 80% or 90% of the health centres that we visited between Mekelle and Aksum were not functional	MSF (2021a)
02.05.2021	Health facilities	Tigray Region	Of 106 health facilities visited by MSF teams between mid-December and early March, nearly 70%	MSF (2021b)

Date	Facility	Location	Status	Reported by
			had been looted and more than 30% had been damaged; just 13% were functioning normally.	

The experience with digital health systems in Tigray

The analysis of the interviews and focus group discussions present insight in the expectations of participants regarding the digital health data system in Tigray. Five themes emerged from the data:

- The experience of using digital systems before the war
- The destruction of the systems during the war
- The capacity building before the war
- The capacity building after the war
- The priorities in rebuilding the digital HISs after the war

The experience of using digital systems before the war

All respondents agreed that in their experience the use of electronic systems for data aggregation, analyses and reporting had a robust foundation in Tigray, but data recording was still mostly paper based. The regional health bureau was committed to realising the information revolution that was directed by the federal ministry of health. One of the goals of the information revolution was to introduce a computer-based reporting system in all health facilities in Tigray. The HMIS administrator of the regional health bureau explained his experience as follows:

> *When we say information revolution, it implies the introduction of computer-based reporting in all health facilities. Without exaggeration, almost all health centres and hospitals were able to send monthly and quarterly reports either by email or other reporting systems - electronically.* (TRHB-P1, HMIS Administrator, face-to-face interview, 16-05-2022, FGD, TRHB)

The HMIS administrator of the regional health bureau explained that DHIS was used for data aggregation, analyses, reporting, feedback, and other activities altogether.

> *In July 2019, we started to report using the DHIS system. In the beginning there were some issues, Interestingly, by resolving the issues one by one progressively, we were able to improve the usability of DHIS*. (TRHB-P1, HMIS Administrator, face-to-face interview, 16-05-2022, FGD, TRHB)

The HMIS administrator of Adwa Hospital also added his satisfaction with the introduction of electronic patient data reporting through DHIS2:

> *We were able to report directly to the district health bureau, regional health bureau, and MOH [Ministry of Health] using DHIS2. … We were using DHIS2 to record aggregate data, do analyses, and send reports based on several indicators. We were also using these for our performance monitoring team (PMT) consumption to track our hospital's progress.* (ADWA-P1, HMIS Administrator, face-to-face interview, 07-06-2022, Adwa Hospital)

The HMIS Administrator of the regional health bureau explained that the Health Extension Programme was implemented in health posts to create health equity at the household level and access to services through referrals to health facilities. This was managed using the CHIS to record health data at the community level to empower health extension workers. Later a mobile application of the CHIS, electronic CHIS (eCHIS) was deployed and piloting was undergone.

> *The bureau decided to commence the piloting of the eCHIS and it was progressing well; however, initiating it in all health posts at the same phase caused issues such as a shortage of tablets. There was a lack of resources to conduct trainings on eCHIS*. (TRHB-P1, HMIS Administrator, face-to-face interview, 16-05-2022, FGD, TRHB)

HMIS experts in the regional health bureau explained that an Electronic Medical Recording system known as SmartCare was introduced in almost all health facilities. At least, the facilities implemented SmartCare in card rooms. Patients were registered in

SmartCare and provided service immediately without requiring patient cards.

> *Before the war, SmartCare was introduced in almost all health facilities in Tigray. Maybe except 10 facilities with no electricity, all health centres and hospitals had EMR [electronic medical record] (SmartCare). It was possible to register most patients in SmartCare to receive registration number. We were almost reaching the stage patients not required to bring patient cards.* (TRHB-P2, Health Informatician, face-to-face, 16-05-2022, FGD, TRHB)

The HMIS expert of the regional health bureau also added:

> *Introducing SmartCare in facilities would enable capturing individual patient data and improve continuum of care.* (TRHB-P3, HMIS expert, face-to-face, 16-05-2022, FGD, TRHB)

A participant of focus group discussion added that there was also a logistics management information system functioning in Tigray. The LMISs such as Dagu and mBrana were used to manage pharmacy stores and vaccines, respectively:

> *We had branch hubs in Mekelle and Shire which were used in their respective coverage areas. At each coverage area there was a Dagu system in each pharmacy store. For vaccine management, Embrana mobile application was in piloting in selected 7 health facilities in Hintalo Wojerat.* (TRHB-P4, logistics management information system expert, face-to-face, 16-05-2022, FGD, TRHB)

Focus group respondents highlighted that a system to support human resource information was also one of the systems functional at *woreda* (district) level before the war. The Human Resource Information System was used to store data about the workforce under the regional health bureau. This enabled the bureau and partners to manage their workforce and to do analyses every 3 months:

> *Every 3 months, the human resource data were analysed and the regional health bureau was able to know the turnout of the workforce at woreda level.* (TRHB-P5, Human Resource Information System expert, face-to-face, 16-05-2022, FGD, TRHB)

The technician of health information of Adwa Hospital reported that patient data were mostly recorded by hand on standard paper forms

at the point of service. Every department has a particular register and patient data should be produced daily. These data were compiled into a tally sheet which contain the aggregated data:

> *Our patient data recording at the point of service and each department such as OPD, IPD, and Emergency uses paper-based registration books and tally sheets. Then we collect the tally sheets and put the aggregated data into DHIS2. Our department (HMIS) used the electronic system DHIS2 system to do analyses and compile reports to the next level.* (ADWA-P2, health information technician, face-to-face interview, 07-06-2022, Adwa Hospital)

Before the war, data were compiled for reporting to be sent in aggregate form to the next administrative level. Aggregated data were prepared in each health facility digitally, using DHIS2, which were prepared for reporting electronically to the regional health bureau. The HMIS administrator of Adwa hospital explained their experience of recording aggregated data to DHIS2 at Adwa hospital:

> *We had a relatively robust system. Though the computers were not enough for the activities we carried out in our hospital, we were able to record electronic data consistently.* (ADWA-P1, HMIS Administrator, face-to-face interview, 07-06-2022, Adwa Hospital)

The analyses results which were produced from DHIS2 was used for health programme planning and reporting by the PMT which monitored the performance of a facility and team at the next level of administration such as district, regional and national health administrations. Feedback was also provided as soon as the report checked by the corresponding authority in the next level:

> *The reports were prepared based on the analyses done using specified indicators in the DHIS2. We use the result form the analyses to present to our PMT team in our hospital and send it to next level as well. We were receiving feedback on the specific reports we submitted.* (ADWA-P1, HMIS Administrator, face-to-face interview, 07-06-2022, Adwa Hospital)

Prior to the war, Tigray had set up a robust infrastructure of electronic health data systems that included DHIS2 for reporting to the Ministry of Health, SmartCare for electronic patient records, and electronic systems to track the logistics in health facilities and the availability and changes in human resources in the facilities. The findings suggest that

there was a relatively high degree of satisfaction with these systems which were generally running well.

Destruction of patient data and digital health systems during the war

Most in-depth interviews and focus group participants expressed that the war had caused a significant amount of damage. Respondents from Adwa Hospital were first-hand witnesses that the facility was closed for 8 months from November to June 2021. The HMIS Administrator of Adwa Hospital reported the following:

> *The war hurt our health facilities. Adwa Hospital stopped providing service for 8 months from November 2020 to June 2021, it was used as a military camp. This means all activities of the hospital stopped: no service delivery, no digital systems, and nothing - everything halted. Before the war started, the hospital had around 300 to 350 patient turnouts daily.* (ADWA-P1, HMIS Administrator, face-to-face interview, 07-06-2022, Adwa Hospital)

The HMIS Administrator of the regional health bureau, who participated in the focus group discussion, observed:

> *All computers were either damaged or stolen, thus it is obvious that the health data and the system that produced health data would be lost along with the computers.* (TRHB-P1, HMIS Administrator, face-to-face interview, 16-05-2022, FGD, TRHB)

One HMIS expert stressed that loss of patient data is a critical problem for care to be delivered and continued without interruption. The destruction of patient data, caused by the war, is enormous, he finds, and it is one factor leading to the collapse of basic healthcare delivery in Tigray:

> *The extent of the data destruction due to the war is huge. Doctors require patient history to carry successful diagnosis out. These put the lives of millions at stake. Patient data is significant for the continuum of healthcare service. If patient data is lost, lives will be lost. Especially, chronic patients missed their clinical follow-ups (Gesesew et al., 2021).* (TRHB-P3, HMIS expert, face-to-face, 16-05-2022, FGD, TRHB)

The HMIS administrator of the regional health bureau expressed his resentment over the destruction that the war caused with critical

damage to the processing of data in the health sector. All the activities that were carried out using electronics, such as recording, aggregation, analysis, and reporting, were no longer functioning:

> *Every activity in our department (HMIS) that requires an Information System has been stopped. The war destroyed everything. They took or destroyed every equipment that would enable us to use the systems we built for decades.* (TRHB-P1, HMIS Administrator, face-to-face interview, 16-05-2022, FGD, TRHB)

A respondent, who is the CEO of Adwa Hospital, added:

> *After the soldiers camped in our hospital, we were not able to come to work for 8 months. Afterward, all equipment in the hospital was looted; all computers were taken. Thus, we could not record patient data electronically.* (ADWA-P3, CEO, face-to-face interview, 07-06-2022, Adwa Hospital)

All participants responded that by the time the interview was held the activities had partially resumed. Ever since the Tigray-based regional government regained control over most of Tigray by 28 June 2021, the regional health bureau started some activities to assess and reopen healthcare facilities. The HMIS department of the regional health bureau was mandated to collect data for aggregation, analyses, and reporting using a special form compiled as a temporary solution.

> *Patient data recording has been resumed using available registers and tally sheets. However, the reporting has altered. The regional health bureau prepared a special reporting form which has few datasets, not more than two pages.* (ADWA-P2, health information technician, face-to-face interview, 07-06-2022, Adwa Hospital)

Although the regional health bureau tried to resume the health service in the region, the reality on the ground was beyond the capacity of the bureau. The extent of the damage to the infrastructure such as communication, electricity, and transportation were bottlenecks for resuming health service immediately. The regional health bureau collaborating with NGOs tried to collect aggregated data on special indicators from facilities using a two-page form. These put the facilities in a difficult situation to find a way to send the form back to the regional health bureau. The regional health bureau was also unable to send feedback to the facilities. To improve the interaction, the regional health bureau was discussing with stakeholders on how to

set up a landline phone for reporting and feedback. The HMIS administrator of Adwa Hospital added:

> *Though we have tried to resume the activities partially, sending a report to the regional health bureau has become very difficult. This is because of a lack of communication, electricity, transportation, and other infrastructure. We have not received any feedback from any authority until recently. There is a rumour that they (TRHB) will start using the landline phone for reporting and feedback.* (ADWA-P1, HMIS Administrator, face-to-face interview, 07-06-2022, Adwa Hospital)

The amount of the registries and tally sheets in facilities was limited. As the health service opened for patients, facilities would not have registries and tally sheets to record data. The CEO of Adwa Hospital said:

> *Even the registration books and tally sheets are going to be finished soon. That means we will stop recording patient data altogether. You can imagine what will happen to the continuum of care going forward without patient data, laboratory equipment, and other essential medical equipment.* (ADWA-P3, CEO, face-to-face interview, 07-06-2022, Adwa Hospital)

The war created significant disruptions on health data recording, aggregation and reporting in the Tigray region with varying impacts on facilities in different location. Adwa hospital, for instance, suffered extensive looting and destruction during the military occupation by Ethiopian and Eritrean defence forces. Facilities were used as camps for soldiers. The soldiers were using wooden racks, papers, plastic materials, and other flammable materials to cook their food. Thus, registration books and tally sheets burnt.

The lack of communication-means such as mobile, Internet connectivity compounded the difficulties. The siege that was imposed on the region further exacerbated the situation, as essential supplies, including food, were scarce. Despite a complete communication and Internet blockade, the regional health bureau and other involved stakeholders sought to resume the recording, aggregation and reporting of health data from accessible health facilities. The determination by healthcare professionals, health facility administrators, and HMIS experts served as the foundation for persisting through dire circumstances. This showed the resilience and

untiring commitment of the healthcare community to resume capturing vital health data, regardless of the challenges brought about by war.

Capacity building of human resources before the war

The introduction of the digital systems in the health sector required the development of new skilled human resources trained in the previous few years. This capacity-building effort brought huge investment from partners and funding organisations. The mission was to employ at least one health information technician at each facility. To succeed in this, continuous training and capacity-building programmes were provided by the Ministry of Health and partners. The HMIS administrator of the regional health bureau explained this as follows:

> *Digitalisation of systems in the health sector should be backed up with health information technicians. If there is at least one health information technician in each facility, the HMIS activities will be carried out without much difficulty. Hence, in Tigray the digitalisation was successful because of the few trained human resources who worked day and night to fulfil the information revolution plan.* (TRHB-P1, HMIS Administrator, face-to-face interview, 16-05-2022, FGD, TRHB)

The HMIS administrator of the regional health bureau added:

> *Information use and data quality were the two most important things that required continuous improvement. Therefore, we had several capacity-building programmes and workshops to bring about continuous improvement not only to our HMIS staff but also to our community in the health facilities.* (TRHB-P1, HMIS Administrator, face-to-face interview, 16-05-2022, FGD, TRHB)

Before the war, the regional health bureau and collaborating partners spearheaded continuous training and capacity-building programmes to ensure the success of the health sector transformation plan. A concerted effort was made, highlighting the collective commitment to fortifying the healthcare workforce with the essential skills required for navigating and optimising the digital landscape in healthcare. The dedication to this capacity-building mission underscores a collaborative and forward-looking approach, which was laying the

foundation for an increasingly resilient and technologically skilled health sector.

Capacity building of human resources during the war

Unfortunately, the onset of the war set everything back to square one. The war commenced when the regional health bureau and involved parties were on the verge of transforming the health sector to the new frontier of digital health:

> … *continuous capacity-buildings were sure to transform the health sector. Digital health requires continuous capacity improvements on the culture of data use and data quality.* (TRHB-P3, HMIS expert, face-to-face, 16-05-2022, FGD, TRHB)

A CEO of Adwa hospital indicated the current status of training:

> … *related to the capacity building, now we have not received any support. Any training for capacity-building needs finances not only for per diem but also for training items. Except for ordinary meetings, we have not started conducting trainings yet.* (ADWA-P3, CEO, face-to-face interview, 07-06-2022, Adwa Hospital)

The war impacted every implementation and investment that was showcasing the transformation of the health sector in the region. Numerous facilities stopped providing services, and healthcare professionals were forcibly displaced from their workplace. Means of communication were disrupted and transportation became impossible. The extensive efforts invested for many years to establish continuous training and capacity-building programmes were interrupted, leading to the collapse of the health system.

Rebuilding of a resilient health data infrastructure after the war

A participant said so far, the effort to rebuild the HMIS is not satisfactory. The regional health bureau started mobilising computers to support the HMIS activities in facilities:

> *The regional health bureau provided us two computers; however, we will not use them for data aggregation, reporting, and activities that need connectivity except for data recording and analyses for the hospital's consumption.* (TRHB-P1, HMIS Administrator, face-to-face interview, 16-05-2022, FGD, TRHB)

A respondent from Adwa Hospital replied that the first step for the rebuilding should be to make DHIS functional where one can report and receive feedback directly to and from the regional health bureau.

> *I expect that the Internet service and other digital equipment will be put in place in few months or a year so that we quickly resume the HMIS activities such as using DHIS2 in our hospital.* (ADWA-P1, HMIS Administrator, face-to-face interview, 07-06-2022, Adwa Hospital)

The participants in the focus group discussion suggested that a comprehensive approach is needed to rebuild HISs, including the use of technology, capacity building for healthcare workers, and collaboration between different stakeholders.

> *The health professionals will have a lion's share in rebuilding the health system. The health sector without the professionals is nothing. Therefore, involving the health providers working with all stakeholders is inevitably crucial in stimulating activities such as capacity building, technology use, and rebuilding HIS.* (TRHB-P1, HMIS Administrator, face-to-face interview, 16-05-2022, FGD, TRHB)

All participants agreed on the need for community involvement in the rebuilding process. They said it is crucial to involve local communities in rebuilding HISs and ensuring that their needs are met.

Discussion: Factors in the resilience of a digital health system

To explain the total collapse of the digital health system in Tigray, it is essential to understand how the resilience of this system was undermined during the conflict. The concept of resilience has evolved over time, traversing various spatial and disciplinary boundaries (Stocker, 2024). The conceptual framework on health resilience proposed by Guha-Sapir and Van Panhuis (2002) provides insight into the significant impact that armed conflict can have on health outcomes. As illustrated in Figure 12.2, the framework identifies three interrelated consequences: primary impact, secondary impact, and the impact on health data and the use of digital systems.

Armed conflict primarily disrupts health systems by causing extensive damage to infrastructure, a consequence recognised as the primary impact. This disruption leads to secondary impacts, including reduced access to healthcare due to the loss of healthcare workers and

facilities, a decline in the quality and quantity of health data collected through health management information systems (HMIS), and interrupted digital health system operations due to the destruction of patient data and the HMIS. The culmination of these primary and secondary impacts is the further degradation of health services, particularly due to the absence of reliable HMIS and patient data.

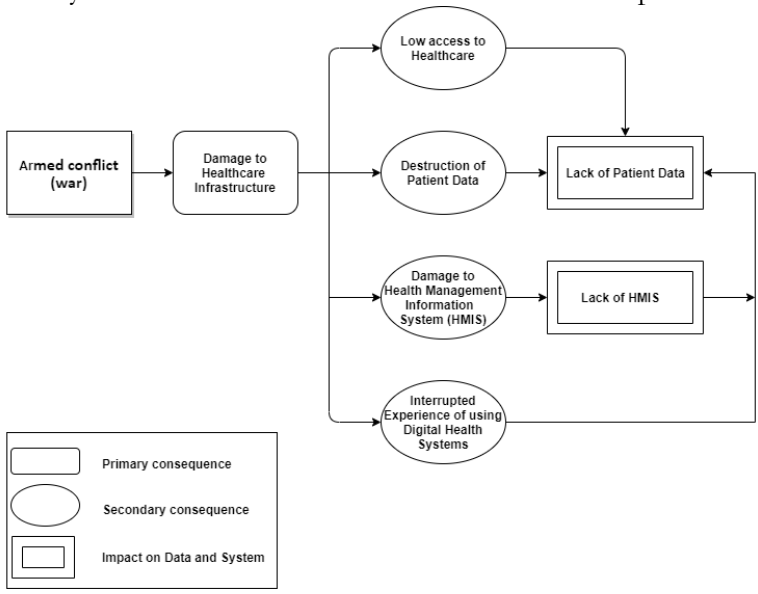

Figure 12.2. Conceptual framework for the impact of armed conflict on health data and HMIS Source: Adopted with modification from Guha-Sapir & Van Panhuis (2002)

The study corroborates the framework established by Guha-Sapir and Van Panhuis (2002), demonstrating how the war adversely affected the health system at multiple levels, leading to the destruction of digital health systems and undermining their overall performance. This framework aligns with broader concepts of health resilience, which are intrinsically connected to the notion of resilience. Resilience is defined as the capacity of systems to plan and prepare for disruptions, endure changes while mitigating their adverse effects, recover swiftly, and enhance performance by learning from experiences (OECD, 2019). Systemic disruption can lead to a critical transformation, resulting in the establishment of a new regime that replaces the original state (Stocker, 2024; Scheffer *et al.*, 2012).

Resilience, therefore, embodies the system's ability to remain within a stable ecosystem state or to rebound once that state has been altered.

Stocker (2024) explains the usefulness of the conceptual framework of resilience in showing that it may lead the system to bounce back or to move into a new regime that is triggered by the disruption. A shift causes a situation to move from an original state called 'regime 1' into a new situation called 'regime 2'. This change is referred to as a critical transition. The hysteresis is the conditions required to create a shift back to the original state of regime 1.

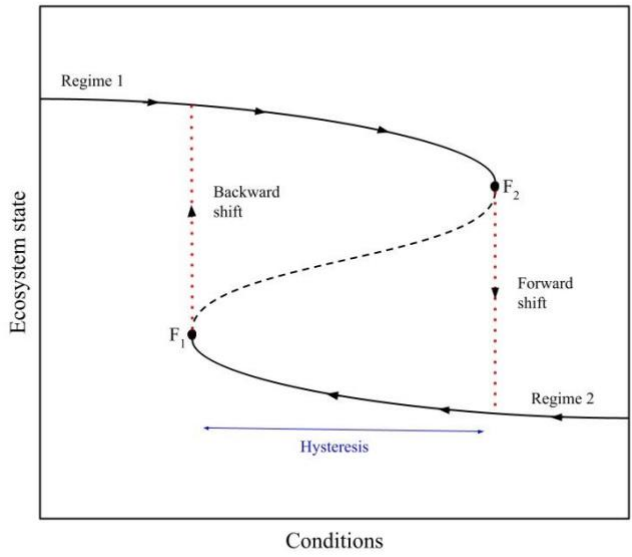

Figure 12.3. A shift between two different regimes

Source: Adapted from Scheffer *et al.* (2012) by J. Stocker (2024)

This conceptual framework can help a reflection on what the outcome of the study means for understanding the factors that determine resilience of a digital health system.

Prior to the conflict, the regional health bureau, along with other stakeholders, initiated digital health transformation activities, establishing digital health as an increasingly important feature within the system (FMOH, 2016). The subsequent collapse of the health

system and digital health infrastructure resulted in a critical transition, leading to a new situation from which returning to the original state would require conditions that are currently unattainable. According to the concept of hysteresis, restoring the system to its original state necessitates meeting certain conditions at significantly higher levels. Consequently, the prospect of rebuilding the digital health support in Tigray to its former state appears unrealistic. It is therefore recommended to consider how digital health systems can be reconstructed within the new context that has emerged, incorporating lessons learned from the failure of system resilience during the war.

In light of this, the post-disruption environment calls for a forward-thinking approach, emphasising the development of a resilience strategy (Rockström *et al.*, 2023). A new system should focus on addressing the identified weaknesses to build a more robust framework capable of withstanding the challenges of future conflicts. This should involve the creation of a comprehensive roadmap for the digital health ecosystem, ensuring a seamless transition from the conventional health system. The capacity of health workers to manage digital health systems remains intact and is a key factor in establishing a resilient digital health landscape. However, the system's reliance on central backbones located outside the region, along with dependencies on Internet connectivity and electricity, critically undermined its stability. Additionally, the inability of health facilities to securely store patient data locally emerged as a significant concern.

A future-oriented roadmap should prioritise the design of a digital health data architecture that ensures safe and secure local data storage, clear ownership of patient data, independence from external backbones, autonomy from Internet and electricity availability, technology-agnostic interoperability, and alignment with local regulations. These elements are essential for constructing a resilient digital health data system (Van Reisen *et al.*, 2023).

Conclusions

This study investigated the destruction of the digital health system in the Tigray war. The study looked at the impacts of war on the digital health data systems of the health sector in Tigray, shedding light on

the challenges and vulnerabilities that emerged during the conflict. It looks for features for rebuilding a resilient digital health data system in the context of the disruptions caused by the war. The findings show three elements:

- The disruption of digital health systems due to damage to the digital health data infrastructure
- A decline in the quality and quantity of health data collected, and interruptions to digital health systems, the destruction of patient data, and loss of healthcare workers and services at health facilities
- A lack of functioning of HISs in the context of the war, siege and Internet and communication blockade

The adoption of HMIS in Ethiopia has become pivotal to the digital data revolution, revolutionising the collection, analysis, and dissemination of health data for decision-making. Before the war, this progress was evident in Tigray, which saw significant advancements in electronic health systems. Leading the charge in implementing HISs, the Tigray Regional Health Bureau invested heavily since the reformed HMIS began in 2015. With guidance from the Ministry of Health, the Tigray Regional Health Bureau developed a structured health information system, enhanced capacity, and deployed digital systems over several years. However, this foundation of digital health collapsed due to the war, which shows that it lacked resilience.

The conclusion is that the health data and health information system in Tigray encountered a devastating shock due to the war. The respondents shared their experience of the use of digital health systems, data management activities, and capacity-building activities in health facilities before and after the onset of the war. They affirmed the destruction of health facility infrastructure, including the HMIS and other health data systems dependent on central backbone systems, and that this destruction was deliberate and systematic. Neither hard copy nor soft copy patient data are now available in most facilities. It has become difficult to manage activities such as recording, aggregation, analyses, and reporting. This has resulted in a health sector that struggles to produce data about health service provision and population health status.

The collapse of the health system and digital health environment in Tigray led to a critical transition, making a return to the original state unlikely under current conditions. Hysteresis suggests that restoring the system would require much higher levels of support for conditions to be met to return to the level of digital health systems in use before the war. More importantly, for the rebuilding of the system, the lessons learnt on what undermined the resilience of the system should be integrated in a future looking resilient digital health architecture.

Instead of aiming to rebuild the original digital health system in Tigray, it is advisable to develop new a digital health system suited to the current situation, incorporating lessons from the failures observed during the war. The experiences of the war should be considered in defining what constitutes a resilient system, as the systems in place were not able to withstand the targeted and systematic destruction of the health system imposed by the war. The issues of concern are the lack of availability of data when links with the central system are disconnected; the lack of control over data at the local level when there is a systematic attack targeting the destruction of the data; and the reliance on a central backbone and on centrally available connectivity, in general, all of which was blocked during the siege. Reliance on one central system undermines resilience. Instead, in a future system it is proposed that the patient data is stored locally, that sources of connectivity are diversified, and that backbones are built on distributed systems. The rebuilding must prioritise the resilience of the digital health system.

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Authors' contributions

The research presented in this chapter was carried out by Maleda Taye, a PhD student at Tilburg University. He wrote the first version of the chapter and attended to all subsequent revisions. He is the first author of this chapter. Araya Abrha Medhanyie advised on the implementation of the research, provided input on the research tools that were used and commented on earlier versions of the chapter. Mirjam Van Reisen edited the chapter at the different stages of production, and she added considerations on the conceptual framework of the chapter.

Ethical considerations

This study obtained ethical clearance from the Institution Review Board (IRB) of the College of Health Science at Mekelle University, MU-IRB 1982/2022 This research was carried out under ethical clearance obtained from Tilburg University Identification code: REDC #2020n13 on "Social Dynamics of Digital Innovation in remote non-Western Communities"

This chapter should be read in conjunction with the 'Note on Content and Editorial Decisions'.

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