Widespread damage to healthcare facilities in Khartoum State, Sudan

10 December 2024

Sudanese American Physicians Association

Yale SCHOOL OF PUBLIC HEALTH
Humanitarian Research Lab

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Executive Summary

This report is a study of hospital infrastructure damage in Khartoum State, Sudan using a cross-referenced analysis of local expert insights, open source data, and satellite imagery across 87 hospitals. The Sudanese American Physicians Association (SAPA) and the Yale School of Public Health's Humanitarian Research Lab (Yale HRL) collaborated to identify widespread damage to hospitals in Khartoum State since the onset of the current conflict. SAPA provides medical aid and healthcare services to hospitals and clinics across Sudan, primarily in Khartoum State.[1]

Hospital damage was assessed using SAPA local experts and open source data as well as satellite imagery from 15 April 2023 to 26 August 2024. Nearly half (47%, or 41 out of 87) of hospitals in Khartoum State were damaged during the first 500 days of conflict. The damage to these hospitals affects at least one-third (711,373 out of 2,134,247) of the patient population in Khartoum State.[2] Approximately half of the damaged hospitals (48.7%, or 20 out of 41) also provided primary healthcare services. The widespread, indiscriminate, and persistent nature of attacks on this critical infrastructure presents short- and long-term risks to population health.

Widespread Damage to Hospitals

Forty-one hospitals sustained damage visible on satellite imagery in 55 separate incidents between 15 April 2023 and 26 August 2024. Eleven of those hospitals were damaged in more than one incident. A damage classification scale was used ranging from no visible damage, minimal damage, partial damage to total damage (*See Methodology, Table 02*). Of the 41 damaged hospitals, eight were minimally damaged and 33 were partially damaged.

Seventy percent of damage incidents occurred between 15 April to 31 December 2023. Most hospitals and damage incidents are located in the central and southern areas of Khartoum State, which are the most densely populated areas, with a population estimated to be 5,941,286.[3] Nearly two-thirds of damaged hospitals are located in Khartoum City (41.58%, or 17 out of 41 hospitals) and Omdurman (26.83%, or 11 out of 41).

Disrupted Health Service Delivery

The ongoing war in Sudan has severely disrupted essential hospital-based healthcare services, including care provided in Emergency Rooms (ER), Outpatient Departments (OPD), Inpatient Departments (IPD), Operation Theaters (OT), and Pediatric Intensive Care Units (PICU). At least 60% of the damaged hospitals provided care in Outpatient Departments (OPD) (25 of 41 damaged hospitals) and Inpatient Departments (IPD) (25 of 41), at least 56% of the damaged hospitals provided care in Operation Theaters (Surgery) (OT) (23 of 41), and nearly half of hospitals provided care in Emergency Rooms (46.3%, or 19 of the 41 damaged hospital). At least one damaged hospital had a Pediatric Intensive Care Unit (PICU). These specialized primary health services included: Integrated Management of Childhood Illnesses, (IMCI), Nutrition, the Expanded Program on Immunization (EPI) and Sexual and Reproductive Health (SRH). Notably, nearly 70% (17 of 25) teaching hospitals in Khartoum State have been damaged, impacting both public health today and the training of future generations of healthcare workers.

Healthcare facilities are essential to the public health infrastructure, including general hospitals, specialty centers, and primary healthcare facilities. The ongoing conflict has limited accessibility to essential healthcare services and specialized treatment across Khartoum State.

Public Health Impact of the Conflict

Despite protections under International Humanitarian Law (IHL), attacks on hospitals in Khartoum State have been widespread, with significant public health implications. Beyond direct harm to healthcare workers and patients, attacks on hospitals disrupt access to healthcare due to patient security concerns, patient accessibility to hospitals, broken supply chains, and high rates of absenteeism and health workforce turnover.

This report's quantification of damage underestimates the actual number and severity of damage incidents due to multiple factors. These factors include: network connectivity disruptions (blackouts) affecting timely and detailed reporting of damage incidents in open sources; human security risks for user-generated reporting; satellite imagery resolution, angle and environmental factors such as cloud-cover affecting quality; and availability of satellite imagery.[4] Incidents of looting , attacks on healthcare workers, and denial of services , which can affect and exacerbate the disruption of healthcare, cannot be assessed solely based on imagery. Nonetheless, the mixed methods approach leverages open and local sources to inform satellite imagery analysis of a non-permissive environment, generating reproducible results. These widespread attacks on hospitals worsen an already weakened healthcare system and limit the provision of healthcare. The findings highlight an urgent need to reconstruct Sudan's healthcare system, with a particular focus on critical facilities in Khartoum and Omdurman.

Background

On 15 April 2023, the conflict in Sudan between the Sudan Armed Forces (SAF), Rapid Support Forces (RSF) and their aligned forces began in Khartoum, Khartoum State, the capital of Sudan. The United Nations Office for the Coordinated of the Humanitarian Affairs (UN OCHA) estimates that the population of Khartoum State is approximately 5,941,286.[5] This conflict has created a humanitarian crisis exacerbated by the disruption of essential health services. Attacks on healthcare facilities have occurred and are still taking place across multiple regions of Sudan since the beginning of the war. Attacks on facilities in Khartoum State not only affect the patient population in those cities but extend nationwide as they include tier-1 referral facilities, teaching hospitals, and over 100 healthcare facilities. Thus, these attacks have wide-ranging effects that go far beyond the impacts felt by the residents of Khartoum and Omdurman alone.[6]

Prior to the ongoing conflict, Khartoum's healthcare system provided a comprehensive range of specialized care. The Sudanese people relied on Khartoum city as the main referral and medical hub for patients from across the country. These healthcare facilities offered specialized treatments such as interventional procedures, complicated surgeries, oncology care, pediatrics specialties, and infectious disease management. The high level of specialization available in Khartoum, concentrated particularly in teaching and referral hospitals such as the Khartoum Teaching Hospital and Omdurman Teaching Hospital, serves as a critical resource for the country's healthcare needs.[7]

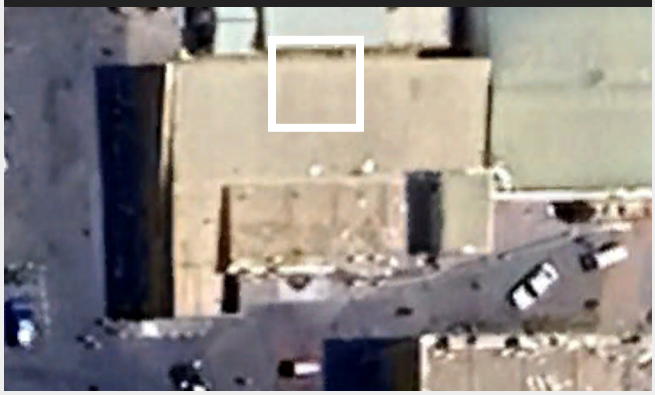
CASE STUDY

Omdurman Maternity Hospital Omdurman, Khartoum State
Damage Observed 14 April–09 July 2023

Omdurman Maternity Hospital in Khartoum State is a teaching and specialized hospital for maternal and neonatal care services. This hospital served as one of Sudan's primary centers for obstetrics and gynecology, addressing high-risk pregnancies, deliveries, and neonatal care for the entire country. The Omdurman Maternity Hospital has around 815 beds, including 140 nursery beds, four intensive care unit (ICU) beds, and four high dependency unit (HDU) beds. These services are crucial in Sudan where there are high maternal and neonate mortality rates.[8]

Yale HRL confirms damage to the roof of Omdurman Maternity Hospital observed between 15 April and 09 July 2023. The hospital is classified as 'partially damaged' as damage appears beyond the surface level, exposing the interior structure of the building. On or around 10 May 2023, multiple sources reported clashes between Sudan Armed Forces (SAF) and Rapid Support Forces (RSF) in the Omdurman area.[9]

Before



14 April 2023 © 2023 Airbus, Google Earth

Damage Observed

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Like other regions in Sudan, Khartoum State's health system is structured as a hierarchical network of primary, secondary, and tertiary care centers to support access and reduce the burden on higher-level hospitals. Primary health centers, located within residential neighborhoods, meet routine and preventive needs; secondary facilities, often based in district centers, treat more complex cases. Tertiary institutions, such as teaching hospitals, provide specialized care. Sudan's Ministry of Health and Khartoum State health authorities assign populations to hospitals based on geographical catchment areas, with primary and secondary centers providing initial treatment and referrals to tertiary hospitals when necessary.[10] This approach reduces the influx of patients while securing access to specialized services for vulnerable populations.[11]

On 5 February 2024, United Nations experts reported that approximately 70 percent of Sudan's healthcare facilities are no longer operational, a majority of which are in Khartoum State.[12] Dafallah et al. reported that less than a third of hospitals in Sudan were operational as of 23 July 2023.[13] On 24 September 2024, the World Health Organization (WHO) reported that Sudan had surpassed 100 attacks on healthcare since the start of conflict on the 15 April 2023. The WHO reported that 75 of these attacks were on healthcare facilities, directly impacting healthcare personnel in 45 cases. Khartoum State is one of the areas most affected by these attacks on healthcare facilities.[14]

CASE STUDY

Omdurman Teaching Hospital Omdurman, Khartoum State
Damage Observed 04 September–31 October and 31 October–06 November 2023

Omdurman Teaching Hospital, with more than 600 beds, is one of the largest general teaching hospitals in Sudan.[15] This hospital provided services including emergency, surgical, and internal medicine center and served as a center for orthopedic training. Omdurman Teaching Hospital played a role in training medical students and healthcare professionals in Khartoum State and across the country.

Yale HRL assesses four damage points to the roof of Omdurman Teaching Hospital observed between 4 September and 31 October 2023 and an additional incident between 31 October and 6 November 2023. The hospital is classified as 'partially damaged', as damage appears beyond surface level, exposing the interior structure of the building. Open sources reported on May 2023 that the medical staff at the Omdurman Teaching Hospital were assaulted, causing the hospital to shut down.[16]

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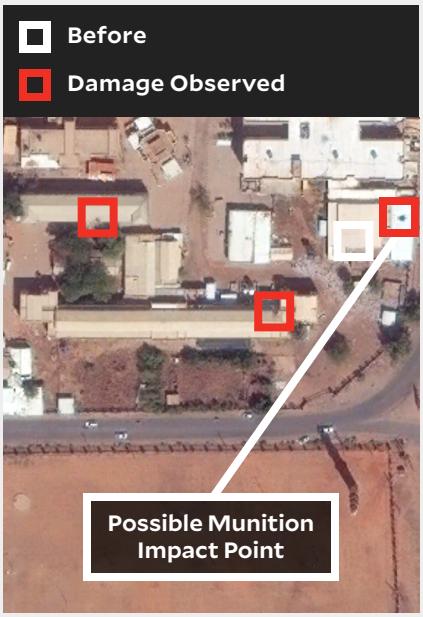

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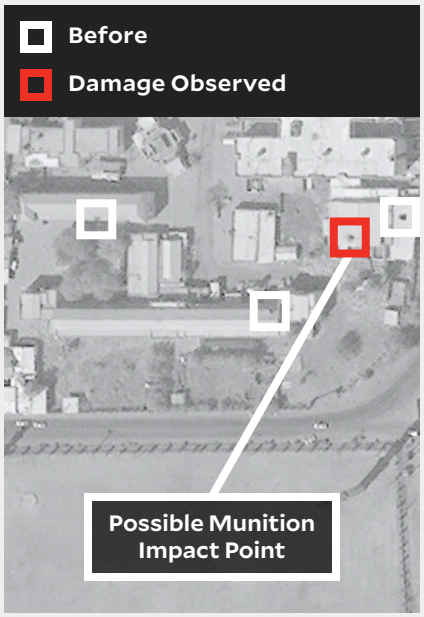

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Methodology

This report assesses damage to hospitals in Khartoum State through the fusion of open and local sources and satellite imagery analysis. Khartoum-area healthcare experts (SAPA), open-source researchers (Yale HRL), and satellite imagery analysts (Yale HRL) conducted the following multi-phase study design:

1. **Developing a comprehensive hospital dataset**
   Yale HRL analysts collated a preliminary list of all hospitals (name, coordinates) in Khartoum State using Arabic and English search terms in Google Maps, cross-referenced by SAPA.

2. **Identifying reported attacks on hospitals**
   Yale HRL analysts cross-corroborated open source data with existing databases of conflict-related attacks on hospitals from Armed Conflict Location & Event Data (ACLED) and Insecurity Insights.[17] Analysts extracted data including hospital facility information and event details such as the date and type of attack.

3. **Assessing structural damage detectable via satellite imagery**
   Yale HRL analysts analyzed publicly and commercially available high-resolution satellite imagery to identify instances of damage to hospitals from 15 April 2023 to 26 August 2024.

4. **Temporal analysis and damage cross-corroboration**
   Yale HRL analysts conducted a temporal assessment of damage incidents and corroboration between open sources and satellite imagery, grouping incidents by timeframes between April to August 2023, September to December 2023, January to April 2024, and May to August 2024.

5. **Public health impact analysis**
   SAPA and Khartoum-area local experts provided pre-conflict information about the services provided and catchment population data for each hospital when available.

Hospital Locations

A cross-referenced database of all hospitals within Khartoum State was developed by Yale HRL and SAPA. Yale HRL manually extracted all structures labeled as "hospital" in both Arabic and English from Google Maps, producing a preliminary dataset of n=136 facilities. SAPA cross-referenced the identified hospital names and locations. Yale HRL and SAPA further reviewed the identified hospitals and removed duplicates, facilities known to be clinics, radiology centers, and veterinary hospitals, resulting in a total of n=87 cross-referenced hospitals.

Attacks on Hospitals

Alleged attacks on hospitals were identified using multimedia content from open sources, primarily user-generated content on social media and local news, along with ACLED and Insecurity Insight datasets.[18] Yale HRL used the keyword "hospital" in the ACLED Data Export Toolset from 15 April 2023 to 26 August 2024."[19] This dataset was then reviewed for false positives and duplicates, resulting in data relevant to a total of 39 reported incidents of attacks on hospitals located in Khartoum State. Yale HRL incorporated Insecurity Insight data from the study period and area of interest to identify 48 reported incidents of attacks on hospitals in Khartoum State. These reported incidents were matched to identified hospital locations by coordinates and name when available.

CASE STUDY

Albuluk Children's Hospital Karrari, Khartoum State
Damage Observed 07 February–31 March 2024

Albuluk Children's Hospital is a teaching hospital specializing in pediatric care and offered services for infants and children, including emergency care, vaccination programs, children with diabetes, malnutrition and treatment for infectious diseases. It was one of the main referral centers for pediatric cases from across the country.

Damage to the roof of Albuluk Children's Hospital was documented between 7 February and 31 March 2024. The hospital is classified as 'partially damaged' as damage appears beyond surface level, exposing the interior structure of the building. Open sources reported that this facility was repeatedly damaged on 4 July 2024 with artillery bombardment.[20]

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Analysts collected, analyzed, and where possible, geolocated, photo and video open source data depicting potential damage for verification through satellite imagery analysis. Open source data analysis protocols adhered to best practices in open source geolocation, as outlined in the Berkeley Protocol for Digital Open Source Investigations.[21] Visual identifiers and observable data from multimedia content such as photos and videos were used to assist with geolocation of these healthcare facilities when such data was available.

An assessment of high confidence through open source verification alone was made based on a combination of multiple reliable and credible open sources and verified and geolocated photo and video data or official statements from known entities with a history of reliability and credibility as well as expertise on the issue (*See Table 01*).

Table 01
Open Source Confidence Classifications

Confidence Assessment	Description	Corroboration Criteria
High	Sources exhibit a high degree of reliability, corroborated by three or more high confidence independent open source references that include verified photo and video data or statements from reliable and credible entities.	Three or more independent sources (ACLED, Insecurity Insight, and various open source) support the same reported incident.
Medium	Sources generally deemed reliable, with corroboration from two independent sources, though inconsistencies may exist.	Two or more independent sources (ACLED, Insecurity Insight, or various open sources) support the same reported incident.
Low	Sources characterized by low reliability or a lack of verification, corroboration from only one source. *However, a low-value source can provide medium or high value content but must be rigorously checked and cross-corroborated with other data sources.*	Only one source (ACLED, Insecurity Insight, or various open sources) supports the reported incident.

Damage Assessment Using Satellite Imagery

The satellite imagery used for this investigation is commercially available, high-resolution imagery captured by Maxar Technologies, Planet Federal, Planet Labs, BlackSky Global, and Airbus. All 87 hospitals were verified by a combination of SAPA local health experts and Yale HRL open source and remote sensing analysts using available data and imagery, across 270 to 400 satellite images available per location. The boundaries of a hospital complex or building footprint were identified using Open Street Map boundaries and cross-referenced with Google Earth and Google Maps.

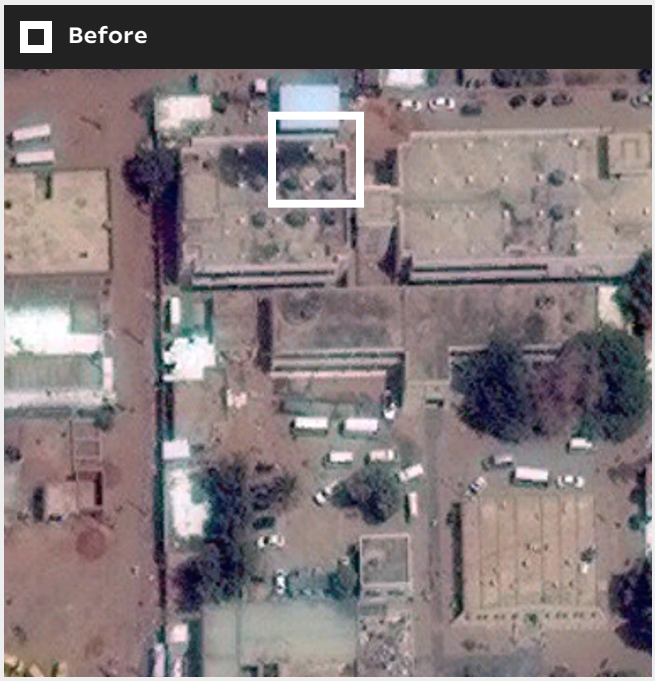
To assess building damage via satellite imagery, multi-temporal change detection was conducted. Multi-temporal change detection is the process of comparing two or more satellite images of the same location captured at various times to detect change.[22] All 87 hospitals were assessed for damage during the conflict. Where there were reported attacks, analysts used available timeframes and event descriptions as well as available ground footage to inform their analysis. Given the combination of factors limiting open source information, such as widespread power and telecommunication outages and population displacement, Yale HRL assessed instances of damage identified solely in satellite imagery as high confidence.

CASE STUDY

AlNau Teaching Hospital Karrari, Khartoum State
Damage Observed 23 September–19 October 2023

AlNau Teaching Hospital, with its affiliation to the medical, dentistry, and nursing school, provided comprehensive services in multiple specialties and served as a key institution for clinical training in various fields. This hospital was known for its emergency surgical services.

Damage to the roof edge of AlNau Hospital was observed between 23 September and 19 October 2023. The hospital is classified as 'minimally damaged' as damage appears limited to the surface level of the roof. Damage observed on satellite imagery is consistent with ground footage from open source reporting.[23]



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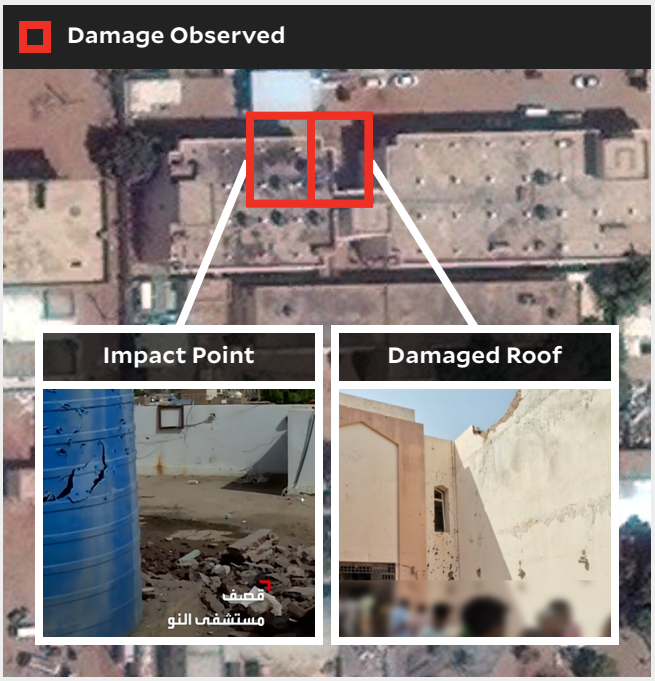

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All damage assessed in satellite imagery is referred to as conflict-related in this report, based on its occurrence during time of conflict. However, not all damage observed can be attributed to conflict events to a high confidence considering seasonal effects such as flooding or structural degradation.

Yale HRL analysts documented the type of damage events, noting dates for baseline and most recent images, as well as pre- and post-damage imagery. The exact damage points were documented as a geospatial point layer and the images used to identify damage were stored with unique identifiers. Two additional Yale HRL analysts reviewed the imagery analysis to minimize errors and reduce individual bias. This secondary evaluation included a review of the documented damage timeframes and the damage classification, and a review with the primary Yale HRL analyst in the case of potential analytic discrepancies. In cases of disagreement, the analysis agreed upon by two Yale HRL analysts (the majority) was accepted as the concurred analytic conclusion.

Damage observed in satellite imagery was classified by assigning each incident one of four damage levels, presented in Table 02. These classifications were applied to the hospital complex, rather than individual buildings. Therefore, if one of two buildings in the same hospital were observed to be totally damaged but no damage was visible on the other building, the overall damage incident was assigned the classification of partial damage. Having documented all separate damage incidents, a classification for the overall location within the study's 500-day period was added as well. In some cases, multiple attacks on a single hospital did not lead to a change in the classification category of damage to the entire facility.

Table 02
Damage Classification[24]

Classification	Description
"Total Damage"	All structures related to a hospital facility are observed to have no structural integrity; roof absent or completely collapsed; lack of standing structure(s).
"Partial Damage"	Substantial damage to roof and/or walls is visible, facility structure(s) appears standing; can include total damage to smaller structures within a facility (e.g., a gatehouse); moderate to extensive debris (debris indicative of damage deeper than surface level; discrete and discernible objects consistent with stone, brick, wood, or other structure materials may be visible on satellite imagery.
"Minimal Damage"	Limited surface damage to roof and/or walls (if visible); can include missing roof tiles and/or light debris (visible but surface-level depth; no discernibly large objects of stone, brick, wood, or other structural materials visible in satellite imagery).
"No Visible Damage"	No visible debris on roof or around walls, no missing roof sections or tiles (not including roofs that may be under construction).

Hospital Attacks and Damage Corroboration

The timeframes for separate damage incidents were defined based on available reporting and visibility on imagery, then grouped into incidents that occurred between April and August 2023, September and December 2023, January and April 2024, and May and August 2024. As analysts were unable to verify all identified incidents in both open source reporting and satellite imagery, timeframes were not matched across sources.

Public Health Impact Analysis

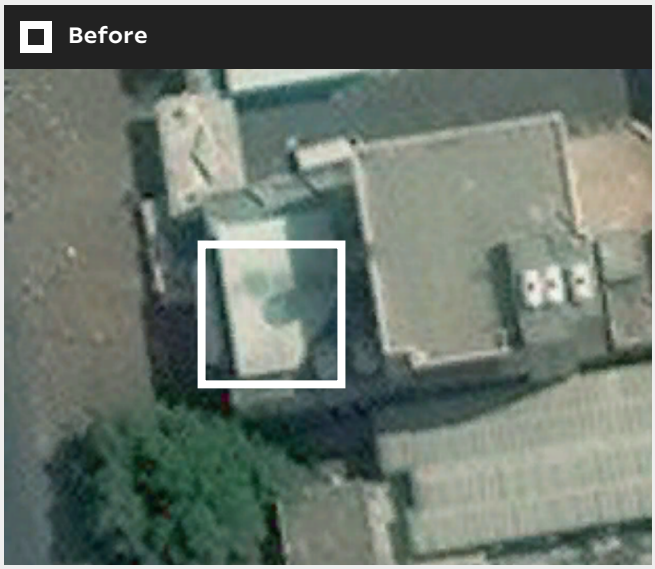
Service provision and hospital catchment population data was collected to analyze the public health impact of attacks on hospitals in Khartoum State. SAPA and additional local experts identified services provided by each hospital pre-conflict. Local community members and grassroot medical providers affiliated with SAPA provided supplemental information to ensure the accuracy of service delivery data. The list of services assessed included "General Services" [Emergency Rooms (ER), Outpatient Departments (OPD), Inpatient Departments (IPD), Pediatric Intensive Care Unit (PICU), Operation Theaters (OT)] and Primary Healthcare Services [Integrated Management of Childhood Illnesses (IMCI), Nutrition (N), the Expanded Program on Immunization (EPI), and Sexual and Reproductive Health (SRH). Each of the 87 hospitals provided some combination of General Services. These hospitals likely provide further specialized care or other healthcare services not captured in this analysis.

CASE STUDY

Radiation and Isotopes Center Khartoum – Alzarra Hospital Khartoum, Khartoum State
Damage Observed 03–29 June 2024

The Radiation and Isotopes Center Khartoum-Alzarra is a teaching hospital and one of the main cancer research centers, focusing on oncology and cancer research and offering specialized oncology care and diagnostic services. This hospital attracted patients requiring oncology care and services from across Sudan.

Damage to the roof of Radiation and Isotopes Center was observed between 3 and 29 June 2024. The hospital is classified as 'partially damaged' as damage appears beyond surface level, exposing the interior structure of the building. Multiple sources reported that between May 2023 and January 2024, the Radiation and Isotopes Center Khartoum was repeatedly attacked.[25]



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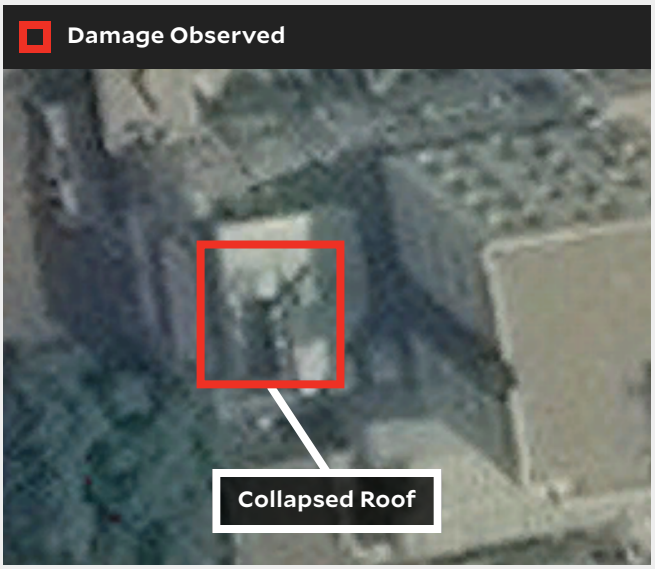

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The hospital population catchment data represents the sum of the number of people assigned to receive services at each of the 87 hospitals, a total of 2,134,247 people. A catchment population is an estimate of the patient population within a hospital's service radius and reflects local patient accessibility to healthcare facilities. SAPA and Khartoum-area experts sourced the population catchment data based on locally available data. There were multiple hospitals for which population catchment data was not available. Missing catchment population data was imputed as the average population catchment for hospitals within the locality after calculating that the locality mean and median were equivalent. The affected population was calculated as the sum of the catchment population of the damaged hospitals divided by the total catchment population of Khartoum.

Strengths and Limitations

This open source and remote sensing analysis fusion methodology, coupled with data from Khartoum-area healthcare experts, generates reliable and reproducible evidence on the impact of the conflict on the health system and population. These findings should be considered in light of several limitations. First, this analysis is limited to damage of hospitals between 15 April 2023 and 26 August 2024. It does not comprehensively include attacks on healthcare workers and patients or conflict-related denial of services. Second, this analysis does not determine each hospital's current functionality, although attacks on health facilities are known to result in absenteeism and affect the degree to which patients attempt to seek care. Third, data limitations may result in an underestimate of damage and disruption to healthcare as assessed in this analysis. Open source data is restricted by Sudan's periods of internet blackouts, including in areas of Khartoum State, resulting in less user-generated reporting on social media,[26] as well as potential underreporting by local media. The type of damage that can be assessed via satellite imagery is limited to exterior structural damage, especially the roof and facade, and damage indicators visible within the vicinity of the facility, such as debris and impact points. Interior structural damage cannot be assessed in satellite imagery except in severe cases. Other typical limitations include cloud cover and environmental effects such as rain and flooding, mist, trees and shadows. The type and amount of imagery available for this analysis was limited to the commercially available imagery uploaded to openly available and subscribed platforms. Fourth, the estimated population affected by the damage and disruption to Sudan's health system is extrapolated from a dataset with significant missing data due to a lack of pre-conflict information. Nonetheless, the equivalence of the mean and median of the reported locality data suggests that the imputed values may closely represent the actual catchment populations. Finally, this analysis does not attribute attacks to specific combatants. However, quantifying the impact of the conflict on population health and the health system represents a first step towards improving civilian protection.

Attribution for specific attacks was not performed in this study due to data limitations. Data that would support attribution to a specific combatant was variably available across attacks and often included conflicting factors that made high confidence not possible. Given these factors, this study did not attempt to assess attribution. Attack attribution may be noted by local sources in materials cited, and readers may reference additional reporting by Yale HRL for specific attribution assessments.[27]

Detailed Findings

SAPA and Yale HRL verified damage with high confidence to 41 of 87 hospitals across Khartoum State, with 55 total incidents during the first 500 days of the conflict. At least eleven hospitals were damaged more than once. A total of 112 attacks on hospitals were reported during the same time. The hospitals that sustained damage served a pre-conflict catchment population estimated to be over 700,000 people, representing 1/3 of the pre-conflict catchment population of Khartoum State. These hospitals provide a range of general and primary healthcare services. Catchment data, derived from demographic surveys and local health records, was provided by SAPA using regional assessment of healthcare provision. Notably, nearly 70% (17 out of 25) teaching hospitals in Khartoum state have been damaged, with significant long-term ramifications for future generations of healthcare workers.

Open Source Reported Incidents

Open source analysts identified 112 attacks on the 87 hospitals in Khartoum State between 15 April and 26 August 2024. These attacks included bombing, shelling, looting, forced entry, and shooting into, encircling, or other forceful interference with healthcare service operations. These attacks were evaluated across a range of confidence levels depending on corroborating material available. Forty-three incidents of reported damage to 30 hospitals were verified at a medium or high confidence standard per the Open Source Verification Standard (*See Methodology*). Of these, fourteen reported incidents at eleven hospitals were both verified to the high confidence open source standard and in satellite imagery analysis. Of the eleven hospitals with multiple attacks, eight were damaged on two separate occasions and three hospitals were damaged on three separate occasions. The majority (61.6%, or 69 out of 112) of damage incidents identified in open source data occurred between April and August 2023 (*See Table 03*).

Table 03
Reported incidents identified across timeframe on open sources

Time period of reported of incidents on Hospitals	April-August 2023 (%, n)	Sep-Dec 2023 (%, n)	Jan-April 2024 (%, n)	May – August 2024 (%, n)	Total
Open Sources	61.6% (69 out of 112)	16.9% (19 out of 112)	12.5% (14 out of 112)	8.9% (10 out of 112)	112

Satellite Imagery Verification

A total of 41 of the 87 hospitals were visibly damaged in 55 separate incidents documented through satellite imagery analysis. Analysts assessed partial damage to 33 hospitals and minimal damage to 8 hospitals (*See Table 04*).

Table 04
Levels of Damage to Hospital Facilities identified in satellite imagery analysis

Level of Facility Damage	"Minimal Damage"	"Partial Damage"	"Total Damage"	Overall Number of Damaged Facilities
Incidents	15	40	0	55
Number of hospitals	8	33	0	41

Almost half of all damage incidents (47.2%, or 26 out of 55) assessed through satellite imagery analysis occurred between September and December 2023. The fewest number of incidents verified through satellite imagery analysis, 10.9% (6 out of 55), occurred between May and August 2024. Most repeated attacks on facilities, 57.1% (8 out of 14), were verified in satellite imagery analysis between September and December 2023 and 42.9% (6 out of 14) were observed between January and August 2024.

CASE STUDY

Asia Hospital, Omdurman Khartoum State
Damage Observed 23 November–08 December 2023

The private Asia Hospital provided surgery, internal medicine, and obstetrics services. Asia Hospital is vital to Omdurman's healthcare network, supporting both the local population and surrounding areas.

Damage to the roof of Asia Hospital was observed between 28 November and 8 December 2023. The hospital is classified as 'partially damaged' as damage appears beyond the surface level, exposing the interior structure of the building. Yale HRL analyzed and geolocated multimedia content to the damaged Asia Hospital.[28]

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Figure 01
Density of Damaged Incidents on Hospitals in Khartoum

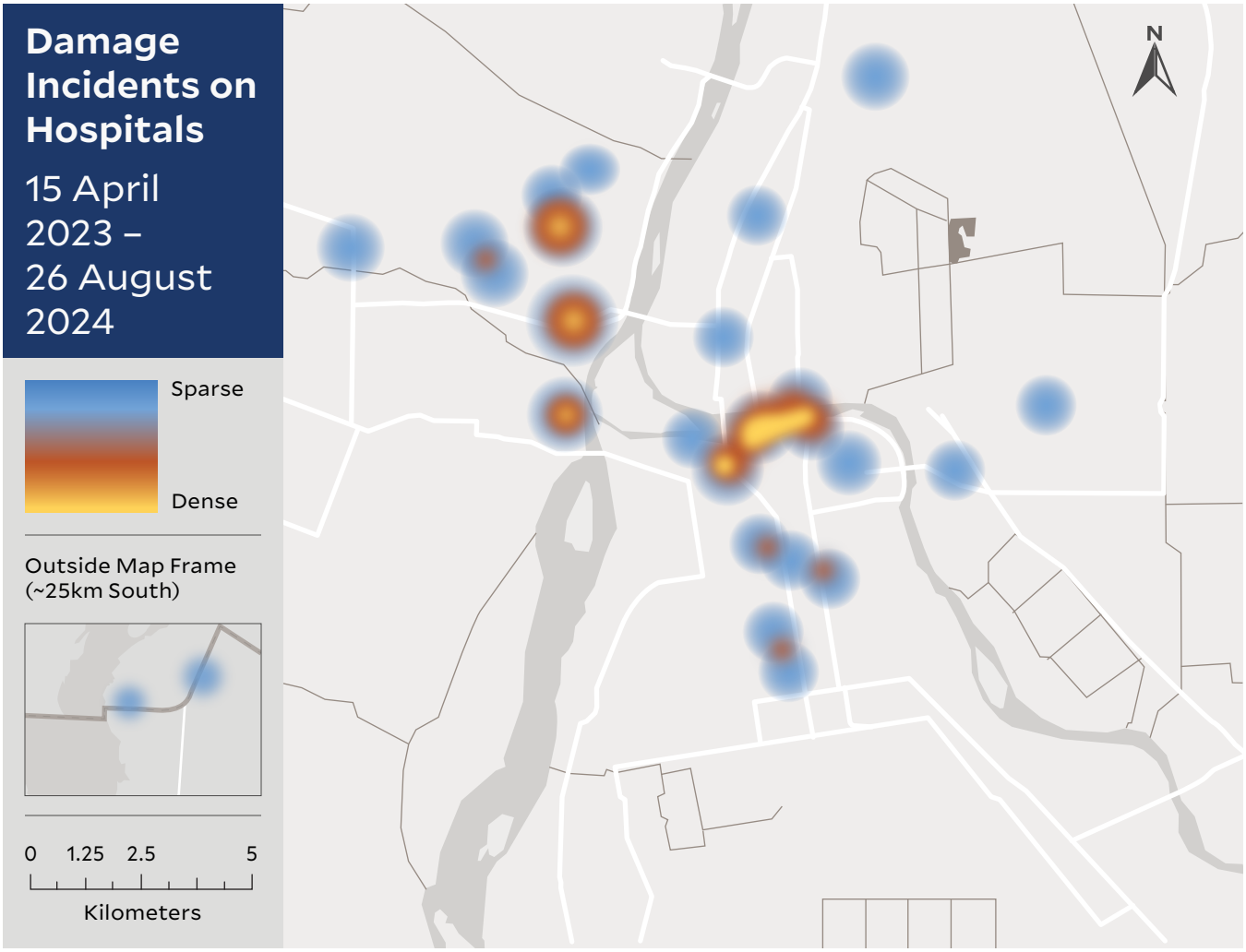

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Table 05
Incidents of Conflict-Related Damage to Hospitals Verified through Satellite Imagery Analysis

Number of incidents	April-August 2023 (%, n)	Sep-Dec 2023 (%, n)	Jan-April 2024 (%, n)	May – August 2024 (%, n)	Total
Total Incidents (Satellite Imagery Analysis)	23.6% (13 out of 55)	47.2% (26 out of 55)	18.1% (n=10 out of 55)	10.9% (6 out of 55)	55
Repeated attacks (Satellite Imagery Analysis)	0% (0 out of 14)	57.1% (8 out of 14)	21.4% (3 out of 14)	21.4% (3 out of 14)	14
Individual hospitals damaged	31.7% (13 out of 41)	43.9% (18 out of 41)	17% (7 out of 41)	7.3% (3 out of 41)	41

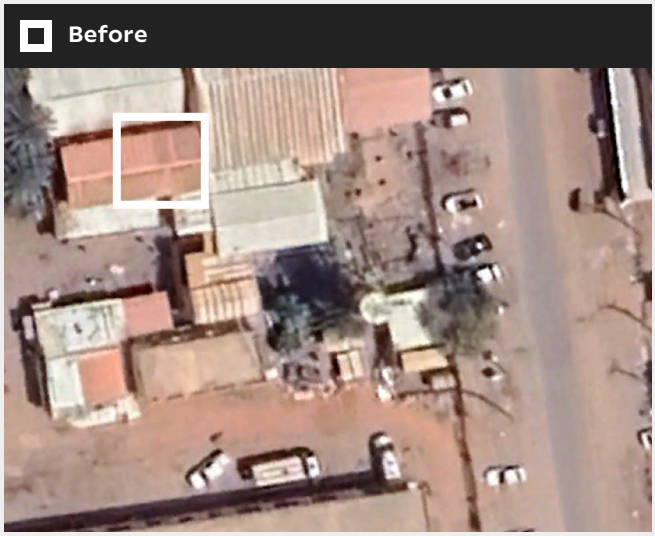
Most damaged hospitals and damage incidents are located in Khartoum and Omdurman localities. These localities are in the most densely populated southern and central regions of Khartoum State. However, while only two (4.9%) of the 41 damaged hospitals are located in Sharg El Nil locality, this represents 100% rate of damage to hospitals in Sharg El Nil due to conflict.

CASE STUDY

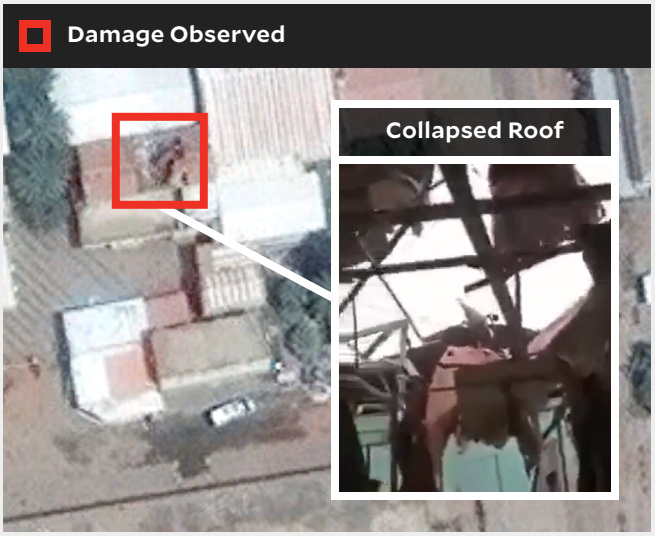
Ibrahim Malik Teaching Hospital Khartoum, Khartoum State
Damage Observed 14 April–23 September 2023

Ibrahim Malik Teaching Hospital is a teaching hospital with the largest emergency department in Khartoum State, with over 80 beds, and serves as one of the main neurosurgery centers in Sudan. This hospital handled trauma care, supported public health emergencies, and trained medical personnel in emergency response.[29]

Damage to the roof of Ibrahim Malik Hospital was observed between 14 April and 23 September 2023. The hospital is classified as 'partially damaged' as damage appears beyond the surface level, exposing the interior structure of the building. Damage was observed in satellite imagery consistent with ground footage from open source reporting. Local media outlets reported that the pediatrics department in Ibrahim Malik Teaching Hospital sustained artillery bombardment on or around 1 May 2023.[30]



14 April 2023 © 2023 Airbus, Google Earth



23 September 2023 © 2023 Maxar, USG-Plus

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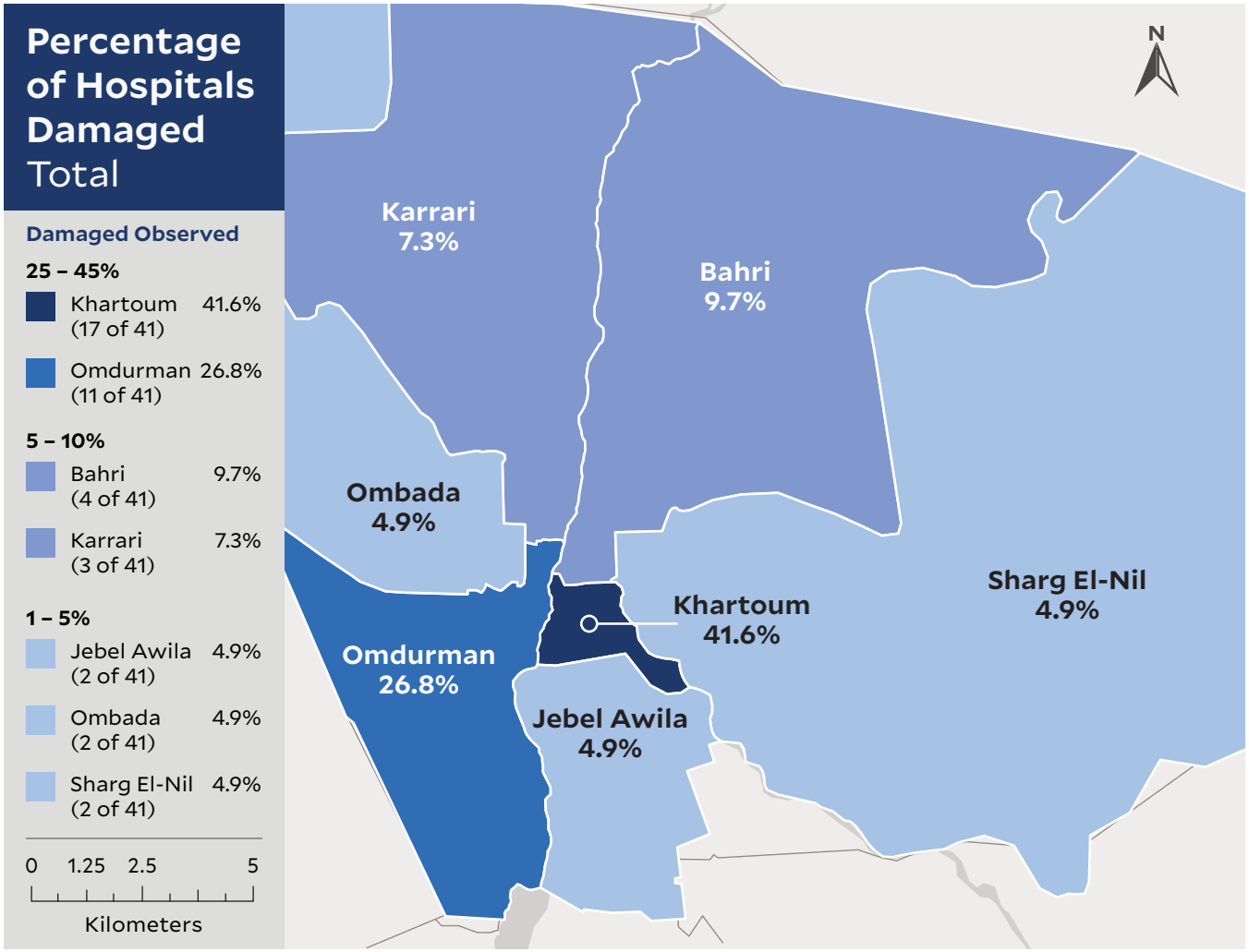
Source: https://x.com/Sudan_tweet/status/1651707154577891331, archived at archived at https://perma.cc/7PHK-4MT5

Table 06
Distribution of Damaged Hospitals Across Khartoum Locality

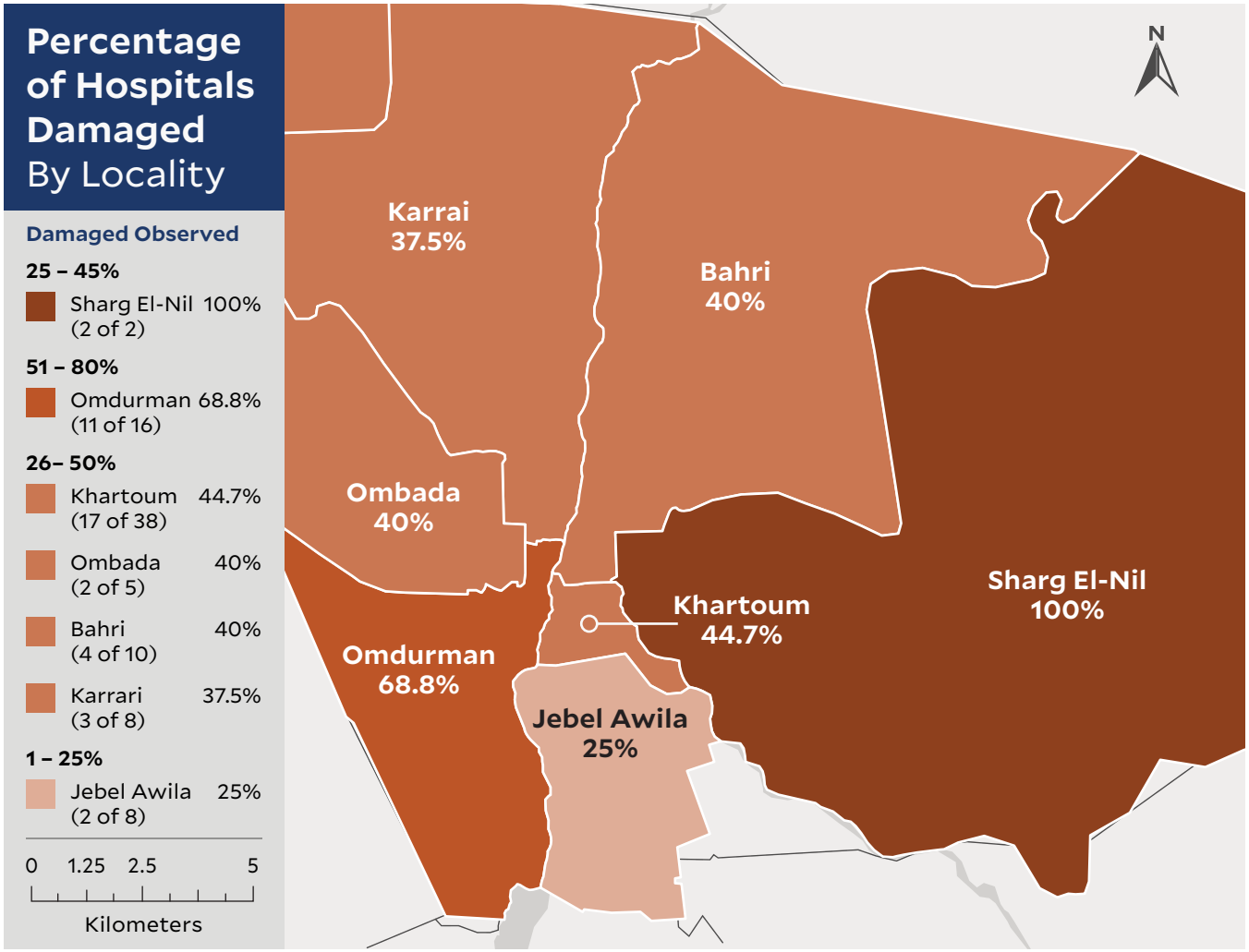
Locality	Percentage of Hospitals Damaged out of Total Hospitals damaged (*See Figure 2*)	Percentage of hospitals damaged out of the locality (*See Figure 3*)
Khartoum City	41.6% (17 out of 41)	44.7% (17 out of 38)
Omdurman	26.8% (11 out of 41)	68.8% (11 out of 16)
Bahri	9.7% (4 out of 41)	40% (4 out of 10)
Karrari	7.3% (3 out of 41)	37.5% (3 out of 8)
Jebel Awilia	4.9% (2 out of 41)	25% (2 out of 8)
Ombada	4.9% (2 out of 41)	40% (2 out of 5)
Sharg El Nil	4.9% (2 out of 41)	100% (2 out of 2)
Total	**41**	**41 out of 87**

Figure 02
Percentage of Hospitals Damaged Out of Total Hospitals Damaged



ESRI, © OpenStreetMap contributors, TomTom, Garmin, Foursquare, METI/NASA, USGS

Figure 03
Percentage of Hospitals Damaged out of Hospitals in Locality



ESRI, © OpenStreetMap contributors, TomTom, Garmin, Foursquare, METI/NASA, USGS

Public Health Impact

Approximately one-third (711,373) of the pre-conflict patient population (2,134,247) was affected by hospitals that were damaged between 15 April 2023 and 26 August 2024.

All hospitals in this dataset provide a combination of what are referred to as "general services." Nearly half (48.7%, or 20 out of 41 damaged hospitals) also provided some form of primary healthcare services. The number of hospitals providing each type of service assessed is presented in *Table 07*.

Table 07
Services Provided by Damaged Hospitals

	Services Provided	Number of Hospitals Damaged
General Services	Outpatient Department (OPD)	25
	Inpatient Department (IPD)	25
	Operation Theater (OT) (Surgery Ward)	23
	Emergency Room (ER)	19
	Pediatric Intensive Care Unit (PICU)	1
	General Services: Specifics Unknown	*12*
Primary Health Care Services	Expanded Program on Immunization (EPI)	20
	Nutrition (N)	15
	Sexual and Reproductive Health (SRH)	10
	Integrated Management of Childhood Illnesses (IMCI)	7

CASE STUDY

Royal Care International Hospital Khartoum, Khartoum State
Damage Observed 14 April–23 September 2023

Royal Care International Hospital, a private hospital, offered specialized services including interventional cardiology services, orthopedics, intensive care services, and oncology.

Debris at the south façade of the Royal Care International Hospital was observed in satellite imagery between 23 and 29 September 2023. The hospital is classified as 'minimally damaged' as damage appears limited to the surface of the façade. On 28 September 2023, *Sudan Akhbar* reported that Royal Care International Hospital sustained aerial bombardment.[31]

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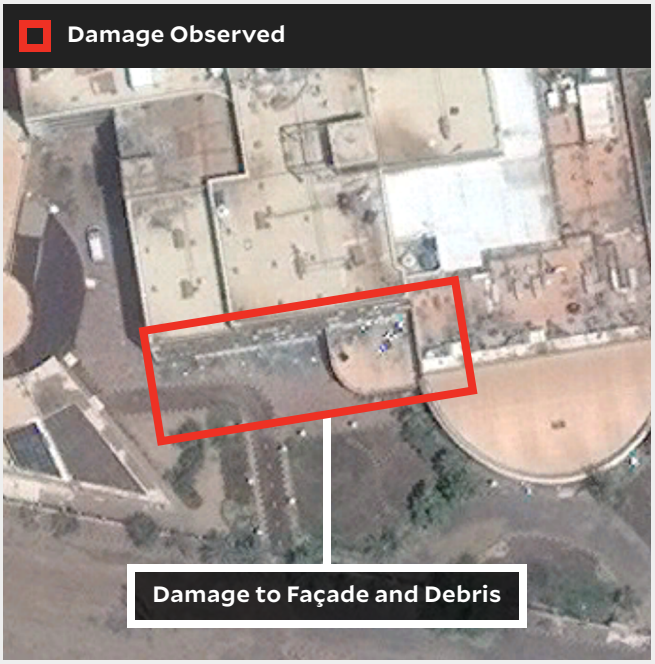

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Teaching Hospitals

Yale HRL verified damage to 17 of 25 teaching hospitals in Khartoum State (68%). Teaching hospitals are defined as a healthcare facility under the Sudanese Ministry of Health (MOH) that serves as a teaching hub for universities and academic institutes. Teaching hospitals help advance the education of medical students and medical professional trainees.[32] These teaching hospitals provide specialized services and training on trauma, breast cancer, and emergency triage, among other areas.

In Khartoum State, these institutions are critical for their clinical services and as concentrated hubs of specialized medical expertise and resources for the Horn of Africa region. These teaching hospitals provided care for complex medical cases and conditions that could not be adequately treated elsewhere in primary or secondary care centers, not only for Sudan, but for the Horn of Africa region. More than 58.5% of the public hospitals in Khartoum have been forced to close due to the ongoing conflict.[33]

CASE STUDY

Sharg El-Nil Hospital Sharg El-Nil, Khartoum State
Damage Observed 14 April–23 September 2023

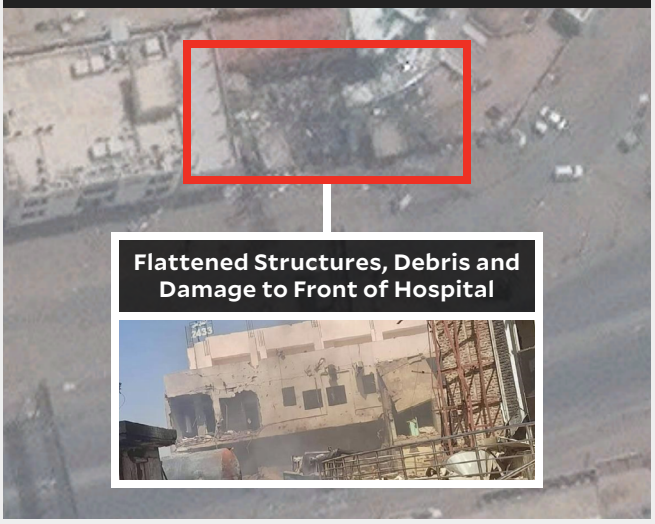
Sharg El-Nil Hospital served the eastern part of Khartoum, providing both general and specialized healthcare and acting as a key referral center for spinal surgery and interventional cardiology services.

Complete flattening of structures, debris and damage to the façade of Sharg El-Nil Hospital was observed between 14 April and 9 July 2023. The hospital is classified as 'partially damaged' as some, but not all structures appear completely destroyed. Damage observed on satellite imagery is consistent with ground footage from open source reporting. Smoke visible in ground-level footage and the extent of damage observed indicates a likely explosion.

Before

14 April 2023 © 2024 Airbus, Google Earth

Damage Observed



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Conclusion

The current conflict has caused extensive damage and disruption to the healthcare infrastructure in Khartoum State since 15 April 2023. Disruptions to immediate healthcare services poses serious risks to individual and community well-being and increases rates of preventable diseases and adverse outcomes, including miscarriages across Sudan.[34] Beyond the immediate security risks to healthcare personnel and patients, the damage to hospitals documented in this report has devastating long-term effects on health and healthcare in Sudan and region wide. These findings demonstrate the urgent need for effective protective measures for Sudan's healthcare system.

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Sudanese American Physicians Association

The Sudanese American Physicians Association (SAPA) is a humanitarian and professional organization committed to safeguarding health and alleviating suffering in crisis-affected communities across Sudan. As the largest Sudanese humanitarian relief organization, SAPA leverages the expertise of Sudanese physicians in the United States to deliver evidence-based health, nutrition, and humanitarian aid in some of the most challenging environments.

As the largest Sudanese humanitarian relief organization, SAPA collaborates with local and global partners to implement high-impact interventions in conflict zones, ensuring access to essential medical services for vulnerable populations. By integrating operational expertise with a commitment to equity and justice, SAPA addresses urgent health, nutrition, WASH, and food needs while contributing to long-term system strengthening and resilience. Guided by professionalism, impartiality, and accountability principles, SAPA serves as a critical bridge between global resources and Sudan's urgent humanitarian demands. For all media queries, please reach out to Dr. Maha Arhait, Media-office@sapa-usa.org.

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