

Readiness of the stroke data ecosystem in Uganda: A multicenter data capability maturity assessment

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Abstract

Background

High-quality stroke data are essential for evidence-based clinical care, surveillance, research, and health-system planning. However, the organizational readiness of health facilities to generate, manage, and utilize stroke data remains poorly understood in many low- and middle-income countries. This study assessed the readiness of stroke data ecosystems for evidence-based care in Uganda using a data capability maturity framework.

Methods

We conducted a multicenter cross-sectional assessment in six health facilities providing stroke care in Uganda. Using the Higher Education Statistics Agency (HESA) data capability toolkit, we assessed four domains of stroke data capability maturity: people and culture, data activities, business processes, and technology. Responses were converted into standardized maturity scores (0-100%). An overall unweighted stroke data maturity score was calculated as the arithmetic mean of the four domain scores, while a weighted composite assigned 30%, 25%, 30%, and 15% to people and culture, data activities, business processes, and technology, respectively.

Results

Unweighted overall maturity scores ranged from 60.8% to 70.0%, with four facilities classified as proactive and two as stable. Weighted maturity scores ranged from 62.8% to 72.1%. Substantial variation was observed across domains, with business processes scoring 44.4–100.0%, people and culture 61.5–76.9%, data activities 30.0–80.0%, and technology 36.4–81.8%. Strengths included governance structures, leadership support for evidence-informed decision-making, standardized data collection tools, and integration of stroke data into routine clinical workflows. Important gaps remained in advanced analytical capacity, routine data quality assurance, interoperability, digitization, workforce capacity, and secure data backup. Hybrid paper-electronic workflows predominated, and only two facilities reported fully interoperable stroke information systems. Five of 24 items showed no between-facility variation, and their exclusion resulted in reclassification of two facilities from proactive to stable maturity.

Conclusions

Participating health facilities demonstrated moderate to high stroke data capability, with relatively strong organizational and governance foundations but important gaps in technical, analytical, and operational capacity. Variation across domains indicates that overall maturity scores may mask specific facility-level

weaknesses that constrain the effective generation and use of stroke data. Strengthening analytical capacity, data quality processes, interoperability, workforce capacity, and secure data infrastructure should complement existing organizational strengths.

INTRODUCTION

Accurate and timely data enable clinicians to monitor patient outcomes, facilitate adherence to clinical guidelines (1), support quality improvement initiatives, identify disparities in access to care, and guide allocation of healthcare resources (2). At the population level, reliable stroke information is essential for disease surveillance, monitoring national and global targets, evaluating interventions, and supporting research that informs health policy (3, 4). As countries increasingly adopt digital health technologies, integrated data ecosystems have become fundamental components of learning health systems that continuously transform routine clinical data into actionable evidence for improving patient outcomes (5).

Despite these benefits, data systems in many low- and middle-income countries (LMICs) remain fragmented and underdeveloped. Data are frequently dispersed across paper records, electronic medical records, disease registries, laboratory systems, imaging databases, and administrative reporting platforms that often lack interoperability (6, 7). Inconsistent documentation practices, inadequate data quality assurance, limited analytical capacity, shortages of trained personnel, and weak governance mechanisms further constrain the effective use of stroke data (8, 9). These challenges reduce the reliability of routine data, limit opportunities for clinical research and quality improvement, and hinder evidence-informed decision-making within health systems (10, 11).

Uganda has made substantial investments in strengthening its national health information system, including widespread implementation of the District Health Information Software version 2 (DHIS2) for routine health reporting and gradual expansion of electronic medical record systems across hospitals (12). Nevertheless, information describing the organizational readiness of health facilities to generate, manage, and utilize high-quality stroke data remains scarce. Existing routine reporting systems primarily support aggregate service reporting and provide limited insight into the broader institutional capacities required for effective stroke data management, including leadership, workforce capacity, governance structures, standardized business processes, digital infrastructure, interoperability, and analytical capability (13, 14).

As specialized stroke services continue to expand in Uganda, understanding these foundational capacities is increasingly important for developing sustainable stroke registries, strengthening routine data systems, and supporting implementation of evidence-based stroke care (15, 16). Stronger data systems can enable timely identification of gaps in stroke service delivery, guide resource allocation, monitor quality of care, and inform targeted interventions to improve access and outcomes along the stroke care pathway, particularly in underserved and lower-level settings (17, 18). Ultimately, investments in stroke data infrastructure should translate into better-informed decisions and more equitable, effective stroke care at the last mile (19, 20).

Data capability maturity frameworks provide a structured approach for evaluating how effectively organizations collect, manage, govern, analyze, and utilize data (21). Unlike traditional assessments that focus primarily on technological infrastructure or data quality, maturity frameworks evaluate organizational capability across multiple dimensions, including people, processes, governance, and technology (22). These multidimensional assessments have been widely applied in health information systems and digital health evaluations to identify strengths, prioritize investments, and guide progressive system improvement (23, 24). However, there is limited evidence on the application of data capability maturity frameworks specifically to stroke data ecosystems in African healthcare settings.

This study assessed the readiness of stroke data ecosystems for evidence-based care in Uganda by conducting a multicenter data capability maturity assessment among health facilities providing stroke services. Using a contextualized data capability maturity framework, we evaluated four key domains; people and culture, data activities, business processes, and technology, to determine institutional capacity for generating and utilizing high-quality stroke data.

METHODS

Study design and setting

A multi-center cross-sectional study conducted among health facilities providing stroke care in Uganda. The study formed part of a broader assessment of the stroke data ecosystem aimed at evaluating the capacity of these facilities to collect, manage, govern, and utilize stroke-related data. Six facilities with different ownership models and levels of care were purposively selected to capture diversity in stroke service delivery. These included four tertiary public referral hospitals, one tertiary private not-for-profit hospital, and one secondary private-for-profit specialist center.

Data capability maturity components

The study was guided by a data capability maturity framework adapted from established health information system maturity models and the Higher Education Statistics Agency (HESA) data capability Framework (25). The framework was contextualized to assess the organization's level of data management maturity. In this study, all four domains of the HESA framework were retained: People and Culture, Data Activities, Business Processes, and Technology. Within these domains, items were reviewed and adapted to reflect the organizational, clinical, and data-management context of stroke care in health facilities in Uganda. This included rewording relevant HESA items to reflect stroke data processes and terminology and incorporating stroke-specific aspects of data collection, management, governance, quality, and use. The adaptation was undertaken by the study team based on the HESA framework and its previous applications in African health settings.

The resulting framework conceptualizes data capability maturity as a multidimensional construct comprising four interrelated domains: (i) People and Culture, (ii) Data Activities, (iii) Business Processes,

and (iv) Technology. The People and Culture domain assess institutional leadership, workforce capacity, accountability, and organizational culture supporting stroke data management. The Data Activities domain evaluates data collection, quality assurance, analysis, reporting, and data use. The Business Processes domain examines governance structures, standard operating procedures, integration of data activities into routine clinical workflows, and sustainability planning. The Technology domain assesses digital infrastructure, system interoperability, data security, patient identification mechanisms, backup systems, and analytical tools supporting stroke data management. Together, these domains provide a comprehensive assessment of organizational capability to generate, manage, and use high-quality stroke data for clinical care, research, health-system planning, and policy development.

The framework has also been applied previously in African health settings, providing a basis for comparison across contexts. These include the INSPIRE assessment across 12 Health and Demographic Surveillance System (HDSS) sites (23) and the Data Science Without Borders (DSWB) Pathfinder assessment across institutions in Cameroon, Ethiopia, and Senegal (26). The current study represents a further application of the framework, extending its use to the assessment of stroke data capability within health facilities in Uganda. This cross-setting application strengthens the potential for comparison and demonstrates the relevance of a common data capability framework across diverse African health-system contexts.

Study participants

The unit of assessment and analysis was the health facility. Within each participating facility, one key informant with primary responsibility for stroke data management or medical records was purposively selected to complete the assessment. A second person was identified to verify the provided information. Where there were discrepancies, the two informants discussed until an agreement was reached. Eligible respondents included medical records officers, health information officers or equivalent personnel who were directly involved in data collection, storage, management, or reporting of stroke information. Where extra clarification was required, respondents consulted relevant departmental records or other members of the stroke care team to ensure accurate responses.

Prior to data collection, administrative approval was obtained from each participating institution. Eligible participants received detailed information regarding the objectives of the study, study procedures, expected duration of participation, potential risks and benefits, confidentiality safeguards, and their right to decline participation or withdraw from the study at any stage without consequences. Written informed consent was obtained from all participants before commencement of data collection. The study collected information on institutional systems and practices only and did not involve access to patient-level clinical records or personally identifiable information.

Data collection procedures and variables

Data were collected using a structured assessment questionnaire developed specifically for evaluating stroke data ecosystems. The questionnaire was informed by published health information system maturity frameworks. The questionnaire consisted of sections capturing facility characteristics and indicators of data capability maturity. Facility characteristics included level of care, ownership, availability of stroke, annual patient volume, annual stroke caseload, age of the facility, age of the stroke unit, and respondent characteristics.

In the data capability maturity section, people and culture domain collected information on the availability of personnel responsible for stroke data management, staff perceptions regarding the importance of stroke data, frequency of staff training, promotion of data use for quality improvement, leadership support for evidence-based decision-making, and accountability for data quality. The data activities domain assessed methods of stroke data collection, adoption of standardized data collection tools, routine data quality assessment practices, analytical capacity, and the use of stroke data for clinical care, reporting, research, and planning. The business processes domain evaluated integration of stroke data collection into routine clinical workflows, availability of standard operating procedures, frequency of data review, governance structures for data sharing, use of data for planning and resource allocation, and long-term sustainability planning. The technology domain assessed the degree of digitization, interoperability with other information systems, implementation of unique patient identifiers, secure data storage, backup mechanisms, access controls, and availability of dashboards or automated reporting systems.

The questionnaire was programmed into Kobo Toolbox to facilitate electronic data collection and minimize data entry errors. Where necessary, the medical records officer consulted institutional documents, standard operating procedures, reporting templates, or electronic information systems to verify responses.

Stroke data capability maturity assessment and analysis

Stroke data maturity was operationalized as a composite measure reflecting organizational capability across the four predefined domains. Individual questionnaire responses were converted into ordinal maturity scores representing increasing levels of capability. Binary responses (no/yes) were assigned scores of 0 and 1, respectively, while ordinal response categories were scored progressively to reflect increasing maturity (**Supplementary Table S1**). These included agreement scales (strongly disagree to strongly agree), frequency scales (never to more than once per year), and levels of digital system sophistication (Paper-based to Fully interoperable electronic systems). Higher scores consistently represented greater data maturity.

For each participating facility, domain-specific maturity scores were calculated by summing item scores within each domain and standardizing the total to a percentage of the maximum attainable score:

$$\text{Domain score} = \frac{\text{Observed score}}{\text{Maximum possible score}} \times 100$$

Standardization enabled direct comparison across domains despite differences in the number of indicators included within each domain. An overall unweighted Stroke Data Maturity Score (SDMS) was subsequently calculated for each facility as the arithmetic mean of the four standardized domain scores per facility.

$$\text{SDMS} = \frac{PC + DA + BP + TECH}{4}$$

Where; PC = People & Culture score, DA = Data Activities score, BP = Business Processes score and TECH = Technology score.

A weighted composite score was computed using predefined domain scores derived from the maturity framework: People and culture (30%), data activities (25%), business processes (30%), and technology (15%) (25). The weighted score was considered the primary measure of data maturity and was used to assign facilities to maturity levels. An unweighted score, with equal weighting across domains, was calculated as a sensitivity analysis to assess the effect of weighting on facility scores and rankings. The weighted domain score was computed as;

$$\text{Weighted domain score} = \frac{\text{Observed score}}{\text{Maximum possible score}} \times \text{Domain weight}$$

The overall weighted score per facility was computed as the summation of the weighted scores from the four domains.

Facilities were further categorized into five maturity levels according to their overall standardized maturity score: Level 0: chaotic, Level 1: reactive, Level 2: stable, Level 3: proactive, and Level 4: predictive (25). In this study, these scores were converted to percentage (%) to ease interpretation (Table 1). These maturity levels describe the progression from fragmented, predominantly paper-based systems to highly integrated learning health systems capable of advanced analytics and continuous quality improvement.

Table 1
Classification of data maturity levels based on maturity scores

Maturity level	Score range	Percentage range (%)
Level 0: Chaotic	0 - <0.50	0 - <12.5
Level 1: Reactive	0.50 - <1.50	12.5 - <37.5
Level 2: Stable	1.50 - <2.50	37.5 - <62.5
Level 3: Proactive	2.50 - <3.50	62.5 - <87.5
Level 4: Predictive	3.50–4.00	87.5–100

Data were exported from KoboToolbox and analyzed using R version 4.6.0. The “dplyr” and “tidyr” packages were used for data cleaning, transformation, and reshaping. Data visualizations, including heatmap, point plots, and bar plot, were generated using “ggplot2”, with “ggh4x” used for enhanced plot customization. The “cowplot” and “grid” packages were used to arrange and refine figures.

Standardized maturity scores were summarized using frequencies and percentages. Domain-specific maturity scores and overall Stroke Data Maturity Scores were calculated for each facility and ranked to facilitate comparison across these facilities. Heatmap was used to visualize domain-level maturity scores across these facilities, and ranked bar charts were produced to compare overall maturity scores.

To maintain the confidentiality of participating institutions, all facilities were anonymized during data analysis and presentation of results. Each facility was assigned a unique identifier (Facilities A-F), and no potentially identifying institutional information is presented. This approach was adopted to encourage candid participation and to ensure that the findings are interpreted as an assessment of system-level data capability maturity rather than as a comparison of institutional performance.

RESULTS

a) Participating health facilities

Six health facilities participated in the data capability maturity assessment, comprising five tertiary hospitals and one secondary specialist center. Four facilities were publicly owned, one was a private not-for-profit hospital, and one was a private-for-profit specialist center. All participating facilities provided stroke rehabilitation services, while five offered acute stroke care, diagnostic imaging, and follow-up services. All facilities reported serving more than 100,000 patients annually, although the estimated annual stroke caseload varied substantially, ranging from fewer than 200 patients to more than 2,000 patients. Most facilities had been established for more than 100 years; however, the age of dedicated stroke units varied from less than 10 years to over 100 years. The assessment was completed by medical records officers in all participating facilities, with four respondents being female and two male (Table 2).

Table 2
Characteristics of participating health facilities

Characteristic	Public				Private not-for-profit	Private for-profit
	Facility B	Facility C	Facility D	Facility E	Facility F	Facility A
Level of care	Tertiary	Tertiary	Tertiary	Tertiary	Tertiary	Secondary
Stroke services	- Acute care - Imaging - Follow-up	- Acute care - Imaging - Follow-up	- Acute care - Imaging - Follow-up	- Acute care - Imaging	- Acute care - Imaging	- Acute care - Imaging - Follow-up
Estimated annual stroke clients	501–1,000	501–1,000	501–1,000	< 200	< 200	> 2,000
Age of the facility	< 10 years	> 100 years	51–100 years	> 100 years	> 100 years	> 100 years
Age of stroke unit	< 10 years	< 10 years	11–50 years	> 100 years	> 100 years	11–50 years
Respondent sex	Female	Male	Female	Male	Female	Female

b) Domain-specific maturity

i. People and culture

The People and Culture domain demonstrated consistently high maturity across facilities, with standardized scores ranging from 61.5% to 76.9% (Table 3, Fig. 1). Two facilities achieved the highest score (76.9%), while the remaining facilities scored between 61.5% and 69.2%. Overall, respondents expressed positive perceptions regarding the importance of stroke data for improving patient outcomes, with most agreeing that stroke data contribute to evidence-based care. Leadership support for data-informed decision-making was also common, with leadership reported to strongly promote evidence-based decision-making in three facilities (Fig. 1). Despite these strengths, dedicated personnel responsible for stroke data management were available in only half (3/6) of the participating facilities. Similarly, staff training on stroke data collection and documentation standards was inconsistent, ranging from never receiving formal training to more than one training session annually.

Table 3

Observed, standardized and Weighted scores of stroke data maturity across selected health facilities

Score category	Health facility	People and culture n = 13	Data activities n = 10	Business process n = 9	Technology n = 11	SDMS %
Observed scores	Facility A	9 (69.2)	5 (50.0)	6 (66.7)	7 (63.6)	62.4
	Facility B	9 (69.2)	4 (40.0)	7 (77.8)	9 (81.8)	67.2
	Facility C	10 (76.9)	3 (30.0)	9 (100.0)	4 (36.4)	60.8
	Facility D	10 (76.9)	7 (70.0)	7 (77.8)	6 (54.5)	69.8
	Facility E	8 (61.5)	8 (80.0)	4 (44.4)	8 (72.7)	64.7
	Facility F	8 (61.5)	7 (70.0)	6 (66.7)	9 (81.8)	70.0
Score category	Health facility	People and culture x/30%	Data activities x/25%	Business process x/30%	Technology x/15%	Overall weighted Score %
Weighted scores	Facility A	20.8	12.5	20.0	9.5	62.8
	Facility B	20.8	10.0	23.3	12.3	66.4
	Facility C	23.1	7.5	30.0	5.5	66.0
	Facility D	23.1	17.5	23.3	8.2	72.1
	Facility E	18.5	20.0	13.3	10.9	62.7
	Facility F	18.5	17.5	20.0	12.3	68.2

SDMS - Stroke Data Maturity Score

ii. Data activities

Data activities domain demonstrated the greatest variability, with standardized maturity scores ranging from 30.0% to 80.0% (Table 3). All facilities reported using standardized stroke data collection tools and routinely utilizing stroke data for clinical care, reporting, research, and planning (Fig. 1). However, approaches to data capture differed substantially. Two facilities reported fully integrated electronic data collection systems, one facility collected data electronically at the point of care, two relied on hybrid paper-electronic systems, and one facility remained entirely paper-based. Routine data quality checks were conducted regularly in three of the facilities, while the remainder performed quality checks only occasionally.

Advanced analytical capacity was particularly limited: only three of five facilities conducted analyses beyond descriptive statistics, and these were restricted to trend or comparative analyses. No facility reported risk stratification, predictive analysis, or modelling, meaning that all facilities scored at most 1 of 3 on the analysis item. This represents a major constraint to using stroke data for evidence-based care (Fig. 1).

iii. Business processes

Business Process maturity ranged from 44.4% to 100.0%, indicating marked differences in organizational governance and operational integration (Table 3). Stroke data collection and reporting were fully integrated into routine clinical workflows in three (3/6) of the participating facilities, while the remainder reported only partial integration (Fig. 1). Formal governance structures for stroke data use and sharing were present in five (5/6) facilities. However, standard operating procedures for stroke data collection, validation, and utilization were absent in three (3/6) facilities. Long-term sustainability planning for stroke data system was reported in four (4/6) facilities. Stroke data were commonly used to support service planning and resource allocation, although this often occurred in half (3/6) of the facilities.

iv. Technology

Technology maturity scores ranged from 36.4% to 81.8%, representing the lowest-performing domain overall (Table 3). Hybrid paper-electronic systems predominated, with five facilities reporting partially digitized workflows. Only one facility continued to rely entirely on paper-based records (Fig. 1). Secure data storage and access controls were universally implemented across all facilities, demonstrating strong institutional commitment to data security. Similarly, dashboards or automated reporting tools were available in five facilities. However, interoperability remained limited. Only two facilities reported fully interoperable stroke data systems, while the remainder relied on partial automated exchange or manual information transfer. Backup mechanisms were also inconsistent, with two facilities lacking secure backup systems for stroke data.

c) Overall stroke data capability maturity per health facility ownership

At individual facility level, two facilities were at the stable level of stroke data maturity (Facility A and C) with the rest (4/6) achieving the proactive level (Table 2). However, this classification was sensitive to the inclusion of five non-discriminating items (F6 – accountability for data quality, F8 - standardized definitions, F11 - data reuse, F21 - secure storage, and F23 - access controls), which received the maximum score across all six facilities (Fig. 1). A sensitivity analysis excluding these zero-variance items resulted in lower maturity scores, with Facility B (61.8%) and E (61.1%) reclassified from Level 3 (proactive) to Level 2 (stable), and Facility A (56.6%) and C (52.4%) being maintained in Level 3 (stable) (**Supplementary Figure S1**).

Stroke data capability maturity varied substantially across domains within facilities at public ownership than across facilities. Within domains, scores ranged from 36.4% to 100.0%, while composite scores

varied more narrowly from 50.0% to 81.8% (Fig. 2). This indicates that differences in data capability were driven primarily by strengths and weaknesses across specific domains rather than by large differences in overall facility-level maturity. Only the business processes achieved the proactive maturity level for all facilities, with the rest varying between stable and proactive.

Weighted data maturity scores, which accounted for the differential contributions of the four domains, ranged from 62.8% to 72.1% (Fig. 3). Weighting changed the ranking of facilities: the unweighted ranking was F > D > B > E > A > C, whereas the weighted ranking was D > F > B > C > A > E. Notably, Facility C moved from sixth to fourth position, while Facility E moved from fourth to sixth. These changes reflect the greater contribution assigned to Business Processes (30%) compared with Technology and Infrastructure (15%) and indicate that facilities with weaker technological capacity may attain relatively higher overall maturity scores when stronger performance in higher-weighted domains offsets these limitations.

Weighted maturity scores varied across facility ownership groups, with differences in the domain profiles contributing to the overall scores (Fig. 4). Public facilities had their highest domain score for Business Processes (22.5/30) and their lowest for Technology (9.2/15). The PNFP facility had a relatively high Technology score (12.3/15), while its Data Activities and Business Processes scores were 17.5/25 and 20.0/30, respectively. The PFP facility showed relatively higher scores for People and Culture (20.8/30) and Business Processes (20.0/30), but lower scores for Data Activities (12.5/25) and Technology (9.5/15). These findings indicate that facilities with comparable overall maturity may have different strengths and limitations across the four data capability domains. Because PNFP and PFP were each represented by a single facility, these patterns are descriptive and should not be interpreted as evidence of systematic differences by ownership.

DISCUSSION

This study assessed stroke data ecosystem readiness across six health facilities in Uganda using a structured data capability maturity framework. Overall, facilities demonstrated stable to proactive data capability, with unweighted composite maturity scores ranging from 50.0% to 81.8%, while weighted scores ranged from 62.8% to 72.1%. Although four facilities were classified as proactive and two as stable, substantial variation was observed across domains and within facilities. Business Processes generally showed the strongest performance, with scores ranging from 44.4% to 100.0%, reflecting relatively established governance structures and integration of stroke data into routine clinical processes. People and Culture also performed relatively well, indicating strong recognition of the value of stroke data and leadership support for evidence-informed decision-making. In contrast, Data Activities and Technology showed greater variability and important operational gaps, particularly in advanced analytical capacity, routine data quality assurance, interoperability, digitization, and secure data backup. The overall classifications were also sensitive to five items that showed no between-facility variation, highlighting limitations in the discriminatory capacity of the instrument in this sample. Collectively, the findings indicate that while participating facilities have foundational organizational structures for stroke

data management, specific weaknesses in technical, analytical, and operational capabilities may constrain the effective generation, linkage, and use of stroke data for clinical care, surveillance, research, and planning.

The relatively high maturity observed in the people and culture domain suggests increasing institutional awareness of the importance of health data in improving patient outcomes. Similar observations have been reported from digital health maturity assessments in other LMICs, where leadership commitment and growing recognition of data-driven decision-making have often preceded investments in digital infrastructure (24). Nevertheless, only half of the participating facilities had personnel specifically responsible for stroke data management, and staff training was inconsistent. These findings reinforce evidence that workforce capacity remains a major determinant of sustainable health information systems (27). Without adequately trained personnel and clearly defined accountability structures, improvements in technology alone are unlikely to translate into better data quality or increased data use.

Business processes represented the strongest domain, indicating that stroke data collection and reporting are increasingly embedded within routine clinical practice. Most facilities reported governance mechanisms for data sharing and use, and stroke data were commonly used for planning and resource allocation. Similar findings have been reported in health information system assessments across Africa, where routine reporting structures are generally well established because of national reporting requirements (28, 29). However, the absence of standard operating procedures in half of the participating facilities demonstrates that governance mechanisms have not been fully institutionalized. Standardized procedures are essential for ensuring consistency in data collection, validation, and reporting, particularly as health facilities transition toward interoperable digital systems (30, 31).

The greatest variability was observed in the data activities domain. Although all facilities reported using standardized data collection tools and routinely generating reports, advanced analytical capacity remained limited, with most analyses restricted to descriptive summaries and trend analyses. This finding is consistent with previous studies demonstrating that many health facilities collect substantial volumes of routine health data but underutilize them for quality improvement, predictive analytics, and clinical decision support (32–34). Building analytical capacity among health information personnel and clinicians is therefore likely to yield substantial benefits by transforming routinely collected stroke data into actionable evidence for improving service delivery.

Technology was the least mature domain, highlighting persistent challenges in the digital transformation of stroke information systems. Hybrid paper-electronic workflows predominated, interoperability between information systems remained limited, and some facilities lacked secure backup mechanisms. These findings mirror broader evidence from sub-Saharan Africa, where fragmented digital systems, inadequate interoperability, and limited investment in health information infrastructure continue to constrain the development of learning health systems (35–38). The predominance of partially digitized systems suggests that many facilities are currently in transition from paper-based to electronic data management. While secure storage and access controls were widely implemented, achieving

interoperable digital ecosystems capable of supporting longitudinal patient tracking, real-time surveillance, and advanced analytics will require coordinated investments in infrastructure, standards, and governance (39, 40).

Although all participating facilities were classified within the stable or proactive maturity level, substantial differences were observed in the underlying domain profiles. Facility C had the highest possible score for Business Processes, reflecting the presence of formal governance structures, however, its Technology domain was substantially weaker, with a predominantly paper-based system. In contrast, Facility F demonstrated strong technological capacity but had comparatively lower performance in People and Culture. These contrasting profiles indicate that the same overall maturity classification can encompass markedly different configurations of data capability. In particular, strong organizational processes may coexist with limited technological infrastructure, while advanced technological infrastructure may not be accompanied by equivalent organizational and workforce capacity to support sustained data use. (41, 42). Facilities with modest digital infrastructure could still demonstrate strong data capability where governance, leadership, and business processes were well established. However, this finding may partly reflect the instrument's scoring design, which gives greater weight to business processes than technology and relies largely on self-reported indicators. Future assessments should therefore incorporate objective measures of implementation and functionality.

Implications for practice

These findings offer practical insights for strengthening stroke information systems in Uganda. First, establishing a national stroke data governance framework is critical to standardize data elements, documentation protocols, interoperability standards, and secure data-sharing mechanisms across facilities. Such a framework could provide the foundation for a national stroke registry and strengthen the availability of data for surveillance, service planning, quality improvement, and research. Second, investments should focus on building analytical capacity, institutionalizing routine data quality assessments, implementing standard operating procedures (SOPs), and expanding workforce training in data management. Designating dedicated personnel for stroke data management within specialized units could further strengthen data completeness, quality, and clinical utility. Third, efforts should prioritize interoperability among electronic medical records (EMRs), laboratory platforms, imaging systems, and national reporting databases. Standardized medical terminologies, unique patient identifiers, and common data-exchange protocols would support continuity of care and longitudinal analysis of stroke outcomes.

Importantly, the observed maturity gaps have direct implications for the ability of facilities to monitor and improve stroke care. The absence of unique patient identifiers in two of six facilities may limit the ability to link admission records with subsequent follow-up, constraining the ability to measure longitudinal outcomes. Limited analytical capacity, with analyses largely restricted to descriptive, trend, and comparative approaches, constrains routine monitoring of process indicators such as time from hospital arrival to imaging or treatment, making delays in acute stroke management difficult to identify.

Similarly, incomplete interoperability between stroke records and imaging or laboratory systems in four of six facilities can hinder timely integration of diagnostic information and consequently limit reliable characterization of stroke subtypes. Lastly, the absence of secure data-backup mechanisms in two facilities creates a risk of permanent data loss, potentially compromising longitudinal monitoring and the completeness of future stroke registries. These findings demonstrate that data maturity is not only an information-system attribute but also a determinant of whether facilities can measure, monitor, and improve key processes and outcomes along the stroke care pathway.

Strengths and limitations

This study represents one of the first applications of a structured data capability maturity framework to assess stroke data ecosystems in Uganda. By examining people and culture, data activities, business processes, and technology, the study provides a multidimensional assessment that extends beyond conventional measures of data quality and digital infrastructure. Inclusion of facilities with different ownership models and levels of care also provides insight into the diversity of stroke data systems within the Ugandan health system.

Among the study limitations, the study included only six purposively selected facilities, limiting generalizability to the entire health facility setting in Uganda. Second, maturity assessments relied primarily on responses from two key informants per facility and may therefore be subject to reporting and social desirability bias, despite verification using institutional documents. Although two respondents were assessed per facility, inter-rater or test-retest reliability was not formally evaluated. In addition, the instrument was not externally validated against objective measures of data performance, such as stroke-record completeness or DHIS2 data quality. Finally, the cross-sectional design provides a snapshot of data capability and cannot assess changes over time or establish associations between maturity and patient outcomes.

Recommendations

Strengthening stroke data ecosystems in Uganda should focus on coordinated improvements in governance, workforce capacity, data management, and digital infrastructure. At the facility level, priority should be given to low-cost, high-yield actions that do not require major digital investments, including developing and implementing standard operating procedures (SOPs), designating personnel responsible for stroke data management, and establishing secure data-backup mechanisms. National stakeholders should develop standardized policies for stroke data collection, governance, and interoperability while supporting the establishment of a national stroke registry. For future national roll-out of the maturity assessment, the instrument should incorporate objective verification measures, such as reviewing a defined sample of stroke records to assess completeness of key data fields, alongside self-reported responses. Health facilities should also conduct routine data quality audits and strengthen analytical capacity. In parallel, longer-term investments in interoperable electronic health information systems and standardized data-exchange mechanisms should be pursued to improve continuity of care, surveillance,

and evidence-based decision-making. Regular maturity assessments should be incorporated into monitoring and evaluation frameworks to track progress and guide continuous improvement.

Conclusions

Participating health facilities demonstrated an overall proactive level of stroke data capability maturity, indicating a relatively strong organizational foundation for the generation and use of stroke data. However, substantial gaps were evident in analytical capacity, digitization, interoperability, and workforce capacity, and maturity varied considerably across domains within facilities. These findings suggest that overall maturity classifications may mask specific system weaknesses that constrain the ability to generate, link, analyze, and use stroke data for monitoring care and outcomes. Strengthening governance, standardized data processes, human capacity, and digital infrastructure, while addressing feasible facility-level gaps—will be important for advancing Uganda's stroke data ecosystem. The contextualized data capability maturity framework provides a useful approach for identifying these gaps, benchmarking facility readiness, and monitoring progress toward more integrated and data-driven stroke care systems.

Declarations

Ethical approval and consent to participate

This study was reviewed and approved by the Research Ethics Committee (REC number: SPH-2025-880) of the School of Public Health, Makerere University, and regulatory approval from the Uganda National Council of Science and Technology (UNCST number: HS7282ES). Administrative clearance was obtained from all the participating healthcare facilities. Participation was voluntary, and informed consent was obtained from all respondents before data collection. Confidentiality of facility responses was maintained throughout the study.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request. To facilitate reproducibility and transparency, a data collection tool was provided as **Supplementary Table 1** describing all the data variables. The R script used for analysis are publicly available on GitHub and archived on Zenodo, and can be accessed using this citation (43).

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

SN: Conceptualization, methodology, data acquisition, formal data analysis, original draft preparation, writing the main manuscript text, prepared figures, revised the manuscript

AK: Funding acquisition, conceptualization, methodology, contributed to data analysis, revised the manuscript

DK, BBB, JNN: Revised the manuscript

TW, MK, AM, AKM, JMS, GN, IB: Data acquisition, revised the manuscript

JM and DG: Conceptualization, Methodology, revised the manuscript

All authors read and approved the final manuscript.

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Figures

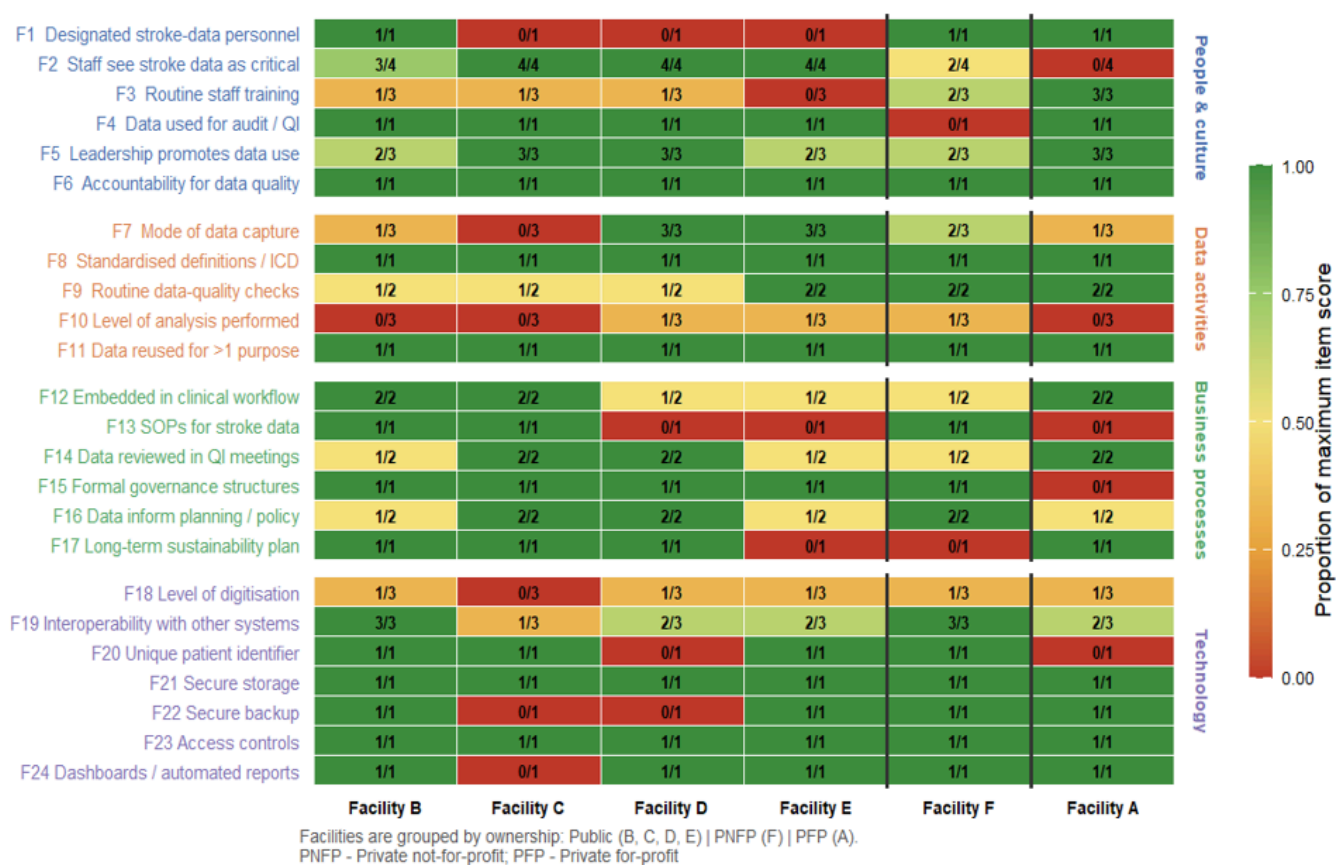


Figure 1

Standardized stroke data maturity per health facility

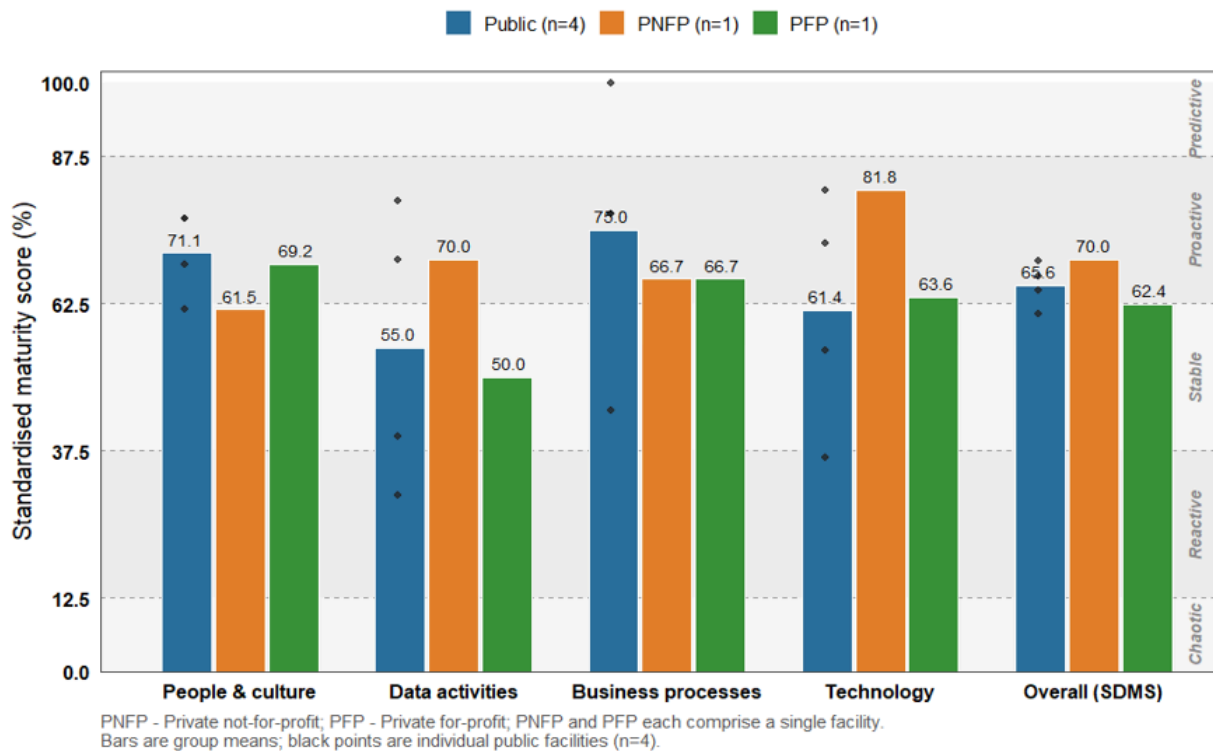


Figure 2

Stroke data capability maturity between facility ownership, across maturity domains

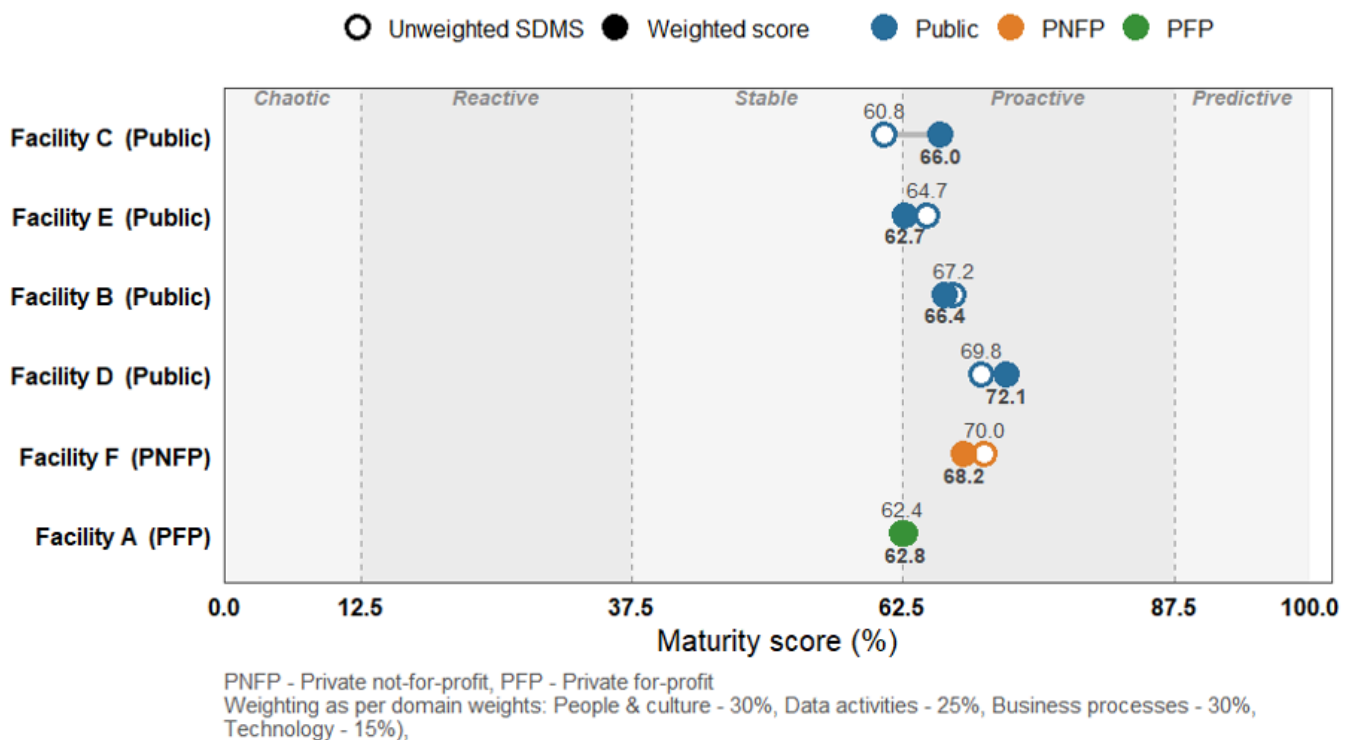


Figure 3

Unweighted versus weighted data maturity score per health facility across facility ownership

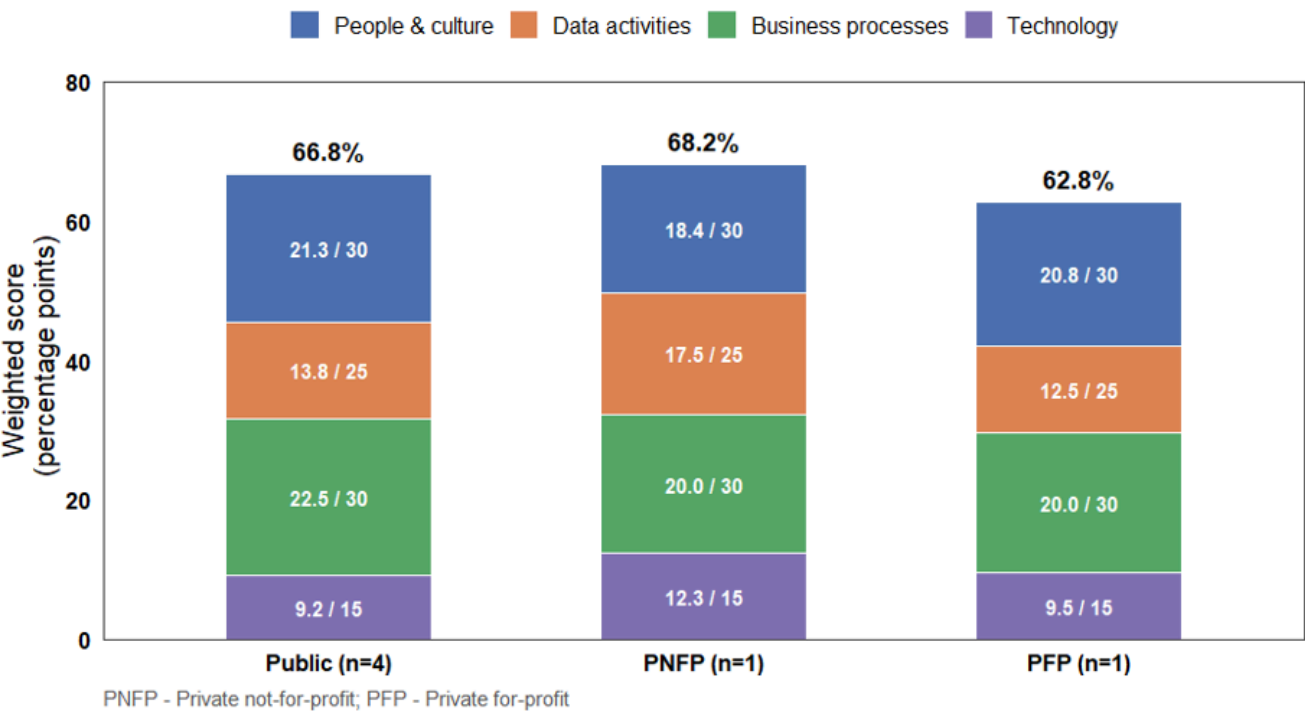


Figure 4

Contributions to the overall weighted scores across facility ownership

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