

Challenges in Implementing a Portable Patient Identification System for Ubiquitous Healthcare in Developing Countries

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Abstract

Patient identification in healthcare information systems (HIS) is often claimed to have been solved by globally accepted information representation standards. This paper illustrates that unfortunately the patient identification problem is not entirely solvable by standards and ubiquitous computing, especially in developing countries. The issue is investigated in the significant context of infectious and drug-resistant diseases within a healthcare facility located in a developing country. The paper investigates and systematises the patient identification issues found, followed by identifying the likely root causes and challenges. This is followed by the definition of a high-level list of the most relevant HIS requirements that could assist in addressing the non-trivial patient identification conundrum, thus clearing the way towards the design and implementation of the next generation pervasive healthcare-enabling HIS.

Keywords: Electronic Health Records, Interoperability, Patient Identification, e-Health, Healthcare Information Systems

1. Introduction

The inability to retrieve reliable patient information, resulting in wasted time and effort, redundant and inconsistent patient records and ultimately leading to a lack of healthcare-related patient security, has long plagued the medical profession. Systematic organisation of patient and associated treatment information in the form of healthcare information systems (HIS), enabled by the current information technology, has constantly been considered a sustainable solution. This solution promised potentially improved efficiency by optimised workflows, patient safety by way of ensuring accurate data where and when required (including data sharing among doctors and institutions) and cost-effectiveness in reducing the record keeping expenses and facilitated billing. Patient privacy, another major concern, was also to be enhanced by consistently meeting privacy regulations through appropriate system policies [13, 18], while the important legal aspect of malpractice was also to be positively addressed [17, 24]. As a result, and following the guidance of United Nations' World Health Organisation (WHO) priorities on health-related millennium development goals [49], most developed countries have invested in- and implemented institution-specific healthcare information systems (HIS), while developing countries are in various stages of implementing such systems [47].

While there are many positive effects of the HIS deployment and signs that applying the proposed multidisciplinary approach involving information technology (IT) investments [12] (although slower compared to other areas [17]) have led to improved value, quality and profitability of medical services [13], failures in HIS implementation have also been recorded owing to various causes such as the technology used, specific healthcare setting, regulatory environment and often in the context of healthcare professionals and other users' resistance to HIS [20, 34].

These global problems are exacerbated in the case of developing countries, many of which do not yet have effectively developed HIS to assist healthcare planning and delivery. As a consequence, in these countries, such initiatives are often performed based on insufficient information and can be influenced by politics, interest groups, socio-economic situation (e.g. poverty, inequality) and importantly, local culture [37]. This not only affects current healthcare delivery by way of inequity, inefficiency and wasted resources, but also future healthcare – e.g. through flawed requirements assessment, program planning and disease trends monitoring and preparedness [6, 39, 47].

Significantly, one of the most fundamental original drawbacks, present from the origins of the HIS concept, unfortunately still persists: patient identification and associated treatment information, in an *unequivocal* form and *where* and *when* it is needed. This paper describes the difficulties encountered in patient identification despite the adoption of HIS abiding by current relevant standards and the challenges that must be overcome in order to effectively address this problem.

2. Current Problems with Patient Identification

The existence of appropriate records of patients and their associated care programs, including disease classification and treatment plans, are paramount in enabling the HISs to effectively support individual patient care, as well as facilitating the creation of accurate aggregate reports in order to properly inform healthcare management and policy-making at the local and global level.

For historic and cultural reasons, typically each organization is using a more or less proprietary version of HIS, aiming to follow health information standards such as Digital Imaging and Communications in Medicine (DICOM) [32], Health Level 7 (HL7) [22, 23], Centre for Disease Control and Prevention (CDC)'s International Classification of Diseases (ICD-10_CM) [10], or WHO's own International Classification of Diseases (ICD v10)[48].

There are two main issues with this approach. Firstly, the above-mentioned standards have certain incompatibilities between them and even between their own versions, as they are regularly evolved for improved capacity, granularity, quality, safety and efficacy (e.g. HL7 v2 vs. v3 [31], or ICD v9 vs. v10 [9]). Thus, following a certain standard is fraught with the danger of inadequate interoperability with other HISs abiding by other standards, or even different version of the same standard [1, 7].

Secondly, implementation of a specific standard in a HIS does not always happen to a necessary and satisfactory extent. For example, HL7 defines an extensive list of patient attributes (i.e. the so-called 'PID Segment') meant for patient identification in recording events (patient admission, discharge and transfer events, care plans, etc.). However, providers are usually unable to completely record and keep track of all of their patients, because of human error and patient data redundancy, which significantly limit the quality of patient data despite the use of Electronic Health Record (EHR) keeping techniques [5, 30, 40].

This paper elaborates on the second aspect, attempting to determine the relevant root causes and challenges using various research instruments as detailed in the next Sections.

3. Research Background, Assumptions and Methodology

3.1. Research Background

One of the co-authors has participated in a healthcare research organization implementing HISs in countries such as Nepal, Pakistan, and Tajikistan. Data cleansing, undertaken as part of the migration from the legacy to the new systems, has found a significant part of patient data in the system to be redundant or inconsistent. The causes of such redundancies and inconsistencies varied, depending on local factors (e.g. socio-economic, culture, etc.). For example, patients moved to new locations and did not inform their treatment coordinators and hence were enrolled as new patients in the same type of care program in the new location. This state of affairs naturally triggered redundant patient identifiers within the HIS built for the healthcare programs and resulted in treatments being restarted rather than continued – which of course meant wasting the previous expenditure on the original treatments.

It was realized that in order to avoid the above problems, one must be able to identify patients a) irrespective of their current location and healthcare provider and / or b) if for some reason their past records could not be located (or if contradictory data was provided by the patient for various reasons). Thus, if patients moved without informing their respective treatment centres and were not able (or not willing) to supply the required information, the healthcare professional should still be able to identify them, locate and access previous treatment process documentation and keep track of them, in order to avoid adverse effects and reduce the cost of treatment, thus improving patient safety and treatment outcomes.

The authors wished to understand the nature and extent of the identification problem in a wider perspective, so as to inform future research seeking suitable ubiquitous solutions [2, 3] for patient identification. Importantly, based on direct experience and primary and secondary data analysis the authors concluded that the assumptions behind the current methods used in modern HISs may not be true in every context – unfortunately, especially in areas of the world where serious diseases are a significant public health problem. Therefore, for this research, multi-drug resistant tuberculosis (MDR-TB), human immunodeficiency virus (HIV) and acquired immune deficiency syndrome (AIDS) patient record keeping was selected as an illustrative example due to the severe potential public health consequences of the issues caused by delayed or erroneous treatments.

3.2. Research Methodology: Instruments and Approach

Several instruments have been employed in this research in order to enable triangulation of the findings. Firstly, a literature review was performed on articles published in scientific journals and conferences by health information technology professionals and experts in the field in regards to issues experienced in deploying and using HIS solutions to ensure the reliability and availability of health records across institutions, cities and states or provinces.

Secondly, to verify the extent of the problem and gather primary data, the authors interviewed medical professionals from Indonesia, Australia, USA and the UK who had been working in the healthcare industry (and had practiced in both developing and developed countries). This was done with the expectation that their personal experience may shed additional light on the secondary data gathered from the literature review.

Thirdly, a case study was used in order to emphasize a typical situation where the assumptions behind current ‘modern’ HISs may not be fully satisfied. The case study involved the analysis of a sample patient database of MDR-TB patients registered for treatment between 2008 and 2012, belonging to an advanced healthcare facility operating in a developing country (Pakistan).

Fourthly, one of the authors was involved in implementing HISs across several countries for various governments under the guidelines of the United Nations World Health Organization (WHO); this included setting up systems in Nepal, Pakistan and other countries. The problems in patient identification in the field have been observed during this time; it was theorized that the problem was rather wide-spread and it was concluded that a deeper

understanding of the underlying causes and mechanisms was necessary before a solution could be suggested (which led to this research).

The researchers adopted an anti-positivistic approach reflected in the interpretivist [21] use of idiographic research methods [8]; in terms of Järvinen's [27] taxonomy, the research method used may be classified as a mix of *theory testing* (confirming that the patient identification problem is indeed prevalent), and *theory creation* (revealing the mechanisms causing the problem).

3.3. Ontological and Epistemological Assumptions Adopted in the Research

From an ontological point of view, in this research the authors adopted a *critical realist* stance [15], acknowledging that “social phenomena are intrinsically meaningful, and hence that meaning is not only externally descriptive of them but constitutive of them” [42] and “meaning has to be understood, it cannot be measured or counted, and hence there is always an interpretative or hermeneutic element in social science” [42]. Critical realism has a stratified ontological view: in addition to the observed, the qualitative methods chosen should differentiate between real, actual and empirical (observed) dimensions of the world. This stance is justified in this research, because if one aims to find the real causes of the problem (patient identification) and later propose solutions to it, the empirical findings are not likely to render a complete picture. More specifically, empirical findings do not necessarily represent what happens, because the events that happen i) may not be observed, or ii) may not necessarily reveal the mechanisms that cause the events that happen (observed or not) [4].

Thus, in addition to exemplifying the observed identification problem (the case study presented further in Section 5), the stance adopted requires the use of other instruments to pinpoint the underlying mechanisms. As a result, the authors used interviews with experts who possess the required insight (see Section 4) in conjunction with a critical literature review (see Sections 1 and 2) to reveal these connections. Finally, the research also relied on first-hand observations during immersion in various organisations (see Section 3.1).

Epistemologically, the anti-positivistic methodology is selected cognisant of the components, sources and limits of knowledge and of the justification of knowledge [33], so as to give a reliable qualitative answer to the research question [16]. The research instruments were selected in order to combine objective and subjective elements and used them to triangulate the validity of the findings [28].

4. Interviews

To assess and verify the seriousness of the patient identification problem, the authors have interviewed representative healthcare professionals involved in HIS operation and development. The issues and underlying causes, as seen by these professionals, have been extracted from these interviews and are summarized in Table 1.

Table 1. Issues identified from interviews.

| Interviewee | Category | Issue (Cause) |
|---|--------------|---|
| Burke Mamlin, Regenstrief Investigator, USA | Power | 1. No access to records, therefore creating new (no reliable electrical power) |
| | Connectivity | 2. Same as above (lack of reliable Internet connection) |
| | | 3. Human Errors in data entry (due to language barrier and spelling differences) |
| | Human error | 4. Clinicians discard old identifiers and issue new one (to match their own clinical identifiers) |
| | | 5. Two different names for the same person (names spelled differently, at different sites) |
| | | 6. Unreliable date of births (patients may not know their own or childrens DOB) |
| | | 7. National identifiers used, but not for medical identification (multiple potential causes) |
| | | 8. Linking of patient data from multiple servers in a timely manner for proper treatment |
| | | 9. Thousands of man hours wasted in manual patient matching |

| | | |
|---|----------------------|--|
| | Duplicate record | 10. More than one identifier assigned to a patient, leading to multiple health records (lack of information about previous identifier's existence) |
| | Tracking | 11. People don't show up for treatments (forget follow-up dates, or have transportation issues) |
| | Integration | 12. Data resides on multiple servers for months; later linking them to patient records is an issue (patient identifiers don't match or change with time, system administrators rely on memory) |
| | Treatment | 13. Tracking of HIV patients' medication (some TB, MDR-TB or XDR-TB patients also have HIV) |
| | Experiment | 14. Many identification methods were tried but all failed (variety of patient identifier methods tried) |
| Dr. Amy Price, Director ThinkWell and University of Oxford, Evidence Based Health Care, USA | Privacy concerns | 1. Data protection (data can be stolen, and misused, e.g., by companies who can profit from identifying patients with significant morbidities) |
| | | 2. System vulnerabilities (hacking attacks) |
| | | 3. Privacy/fear of not being accepted (some tribes do not allow female members to visit hospitals) |
| | | 4. Data leaks, resulting in illegal profiteering (misuse by financially interested companies) |
| | Knowledge limitation | 5. Lack of technical knowledge in researchers (malicious attacks) |
| | | 6. Lack of communication between various data systems |
| | Financial limitation | 7. Lack of funds for expansion (Govt limit budget) |
| | | 8. Access to funds for research and vulnerability patching (limited budgeting from the government) |
| | Human error | 9. Inaccurate data collection (missing to fill in some fields – sometimes deliberately) |
| | | 10. Data manipulation errors (matching records manually can result in incorrect records) |
| Dr. Akhtar Muhammad, Medical Officer World Health Organization, Indonesia | Reporting | 1. Recording and reporting (multiple records of the same patient may give inaccurate estimates) |
| | Integration | 2. Multiple electronic systems are being used (many systems used at different stages of treatment) |
| | | 3. Lack of systems integration (legacy systems do not support new protocols) |
| | Human errors | 4. Patient relapses from TB to MDR-TB, while in the program (re-enrolled as new patient) |
| | | 5. More time spent in creating reports (systems having multiple records of a single patient can be used to generate reports automatically, so they are created, checked and re-checked manually) |
| | Integration | 6. Impact on planning, budgeting, resource mobilization and disease control (financial issues) |
| Maia Sauren, Senior Business Analyst, Thought Works, Australia | Power | 1. Reliable power (developing countries have frequent power outages) |
| | Documentation | 2. Free software has loopholes or errors (no development path or guarantee for future growth) |
| | | 3. Single/stand-alone sites (sites that do not have internet connectivity to transfer data) |
| | Integration | 4. Patient records expired (patient visit after long period of time) |
| | | 5. Merging multiple records issue (with the same name / spelling) |
| | | 6. Language issues (difference of dialect from region to region) |
| | Human error | 7. Multiple records of the same patient (patients/clinicians use different regional spellings of names) |
| | | 8. Human typos (missing a keystroke, or hitting another one while working fast) |
| | | 9. Name changes (use of nicknames, different from names on national identification document) |
| | | 10. Different spelling in different languages (language barrier) |
| | | 11. Patients deliberately give different names (e.g. nicknames not on the national ID document) |
| | | 12. Danger for patient (patients with same name, can be mixed up and be given the wrong drugs) |
| | Connectivity | 13. Taking drugs without prescription or doctors' advice (Drug shopping) |
| | | 14. Systems are down (power failure, hacker attacks, natural disaster disrupting connectivity) |
| | | 15. Internet outage (natural / man-made disaster disrupting connectivity) |

| | |
|------------------------------|---|
| Human error; Connectivity | 16. Have no patient management system at all, or having one that does not work properly (legacy system, that does not integrate with new systems) |
|------------------------------|---|

4.1. Discussion of the Findings

The interviews have highlighted current major issues in patient identification. According to the interviewees, the most common cause of problems especially in developing countries are internet connectivity and power outages, triggering unavailability of the HIS servers and thus impossibility for the clinicians to identify their patients. In practice, this leads to the creation of multiple records of the same individual, which can also reside on the server for long periods of time before being detected.

Once such a scenario has occurred, the cure is not trivial. Thus, even if the technical team attempts to merge such records, they can also make accidental changes. Even if there is a standardised and (semi-)automated process to merge and link patient records into a single master index file (which in many but not all cases is possible), it can take several thousands of hours, with some records still not correctly linked in the end (as it may not be feasible to cover all possible cases). More importantly, due to the fact that often duplicate records are left for months on multiple servers, later on there may be no way of unequivocally identifying which data belongs to which patient.

Another issue highlighted by one of the interviewees was patients trying to hide their identity for 'drug shopping'. Thus, patients buy drugs from the pharmacy without prescriptions, resulting in side effects upon administration without the individual being aware of the danger involved. Other patients, while taking medication as per the advice of a medical professional, may hide this information on seeing another doctor ('doctor shopping') to receive another drug - which may not be compatible with the first.

Patients may also hide their past medical history from the medical professional, which can lead to allergic reactions or other adverse effects. Privacy concerns, as stressed by one interviewee, are the main reason why patients sometimes hide past medical history or medication from medical professionals. Thus, they fear they might become victims of pharmaceutical corporations forcing them into buying expensive drugs, be discriminated in job seeking or at work or fall prey to the insurance companies. Data from HIS might be able to be obtained through unethical means, and be used against them (e.g. in legal cases).

Lack of effective data input standardization and validation can also create redundant data in the HIS. For example, the local language can become the basis of multiple record creation, whereby data entry personnel might accidentally (e.g. due to language differences) use different spelling of a patient's name thus creating multiple records of the same person.

From the above it can be concluded that unfortunately there is no reasonable possibility to accurately identify an individual with 100% certainty if relying solely on current HIS capabilities. Main steps towards a solution would be solving the current integration and standardization issues and reliably ensuring the anonymity of patients. Thus, according to multiple interviewees, there is a need for a universal system that not only caters for the patients in a single medical centre, but a cross-institutional one capable of linking, tracking medication, updating health records, and making past medical history available during follow up irrespective of patient location or ability to self-identify.

If the above were possible, report generation would consume less time and resources and allow improved budgeting, resource mobilization and better care. In addition, from the public health and disease control point of view, the accuracy of outbreak prediction in certain areas of interest could be significantly improved, allowing preventative measures to be taken to build preparedness for the effective containment and fight of epidemics [50].

5. Case Study: Healthcare Information System Database

5.1. The Research Site

The Indus Hospital (TIH) in Karachi, Pakistan [45] is a non-profit organization providing high-quality care free of cost to its patients and having treated more than 2.6 million patients to date. The tuberculosis (TB) Program at TIH is funded through philanthropic donations, corporate social responsibility (CSR) funding and The Global Fund (TGF) [44].

Since 2008 TIH and Interactive Research Development (IRD) [25] (TIH's technical partner for the TB program) have approached TB control using a holistic healthcare delivery paradigm. Thus, the HIS developed for this purpose had more than 3,000 Directly Observed Treatment Short-course (DOTS) and 400 MDR-TB patients actively treated as of 2012. The research site database records show that 1,000 patients had been enrolled in the MDR-TB program (between 2008 and 2012), with 400 of them actively on treatment using funds raised from private donors and corporate social responsibility donations for medicines, food baskets, transportation etc.

TIH is one of the recipients of USD \$153 million grant from TGF's 'Round 9' grant to National Tuberculosis Program (NTP) Pakistan, to scale up programmatic management of TB over a five year period from 2011 in the provinces of Sindh and Balochistan. The healthcare facility features a unique bio-safety level (BSL) 3 laboratory in Pakistan, operating since 2008-2009 for drug susceptibility testing of TB-infected patients registered for care at TIH and other locations in the province of Sindh. For the purpose of this research, the researchers requested TIH to provide access to the database storing information on TB, more specifically DOTS and MDR-TB or XDR-TB (eXtensively Drug Resistant-TB) patients. The database implementation was funded from the above-mentioned TGF support for the fight against TB, malaria and HIV/AIDS [43].

5.2. Data Gathering

The researchers and co-investigators obtained ethics permissions for the data gathering protocol from the research institution involved [19] and the TIH Internal Review Board (IRB) [46]. Accordingly, a copy of the MDR-TB database was obtained, with patient records de-identified using encryption for privacy reasons. The advantage of using this database for analysis was that redundant / duplicate patient records had previously been manually identified (following a costly and laborious human activity). Therefore, it was expected that two patient records belonging to the same patient would map to the same encrypted value, thus facilitating duplicate identification while avoiding the need for the researchers to perform data cleansing for the purposes of this investigation.

5.3. Analysis

The data was imported into a MySQL version 5.5 database server, running on an Ubuntu 12.04 operating system. Subsequent to the successful data import, the following queries were executed on the database:

```
Select count(patient_id) as number_of_patients      (1)
  from patients;
```

This query returned: number_of_patients = 1000.

Using the table 'patient_identifier' retrieve the number of identifiers assigned:

```
Select count(identifier) as number_of_identifiers  (2)
  from patient_identifier;
```

The above query returned: number_of_identifiers = 1046.

Using the table 'patient_identifier' find the number of duplicates:

```
Select patient_id as person_id, (3)
       count(identifier) as duplicates
from patient_identifier
   group by patient_id
   having count(identifier)>1;
```

This query returned: duplicates = 43.

The percentage of duplicates in the database of 1,000 patients was obtained by executing the query:

```
Select duplicates / number_of_patients as percentage; (4)
```

The result of the above query returned the percentage as being 4.3.

5.4. Discussion of the Results

This representative example illustrates that patient identification issues can exist even in an advanced healthcare facility like TIH. Although the percentage of errors found is small, it must be closely monitored by data experts for rectification, as the consequential errors in treatment can be life threatening in such serious diseases.

Considering that the relatively small sample database had 4.3% of patient identification errors, then in a facility catering for approximately 500,000 patients of all kinds on a yearly basis (such as TIH, including HIV/AIDS and DR-TB), having a similar level of identification error could mean that an estimated 21,500 patients in a single facility might end up being treated (or having been treated) incorrectly, due to patient identification issues. Given that countries have populations numbering millions, 4.3% results in tens of thousands, which is a significant order of magnitude, especially considering the highly infectious characteristic of the diseases (and the resulting substantial risk of epidemic).

6. Challenges in Implementing Portable Patient Identification in HIS

After an analysis based on interviews, database analysis, literature review and personal experience, it has become evident that due to a number of factors, current practices and (information) technologies do not solve the issue of patient identification reliably in order to effectively determine a patient's identity for treatment purposes. The challenges found to arise when developing and implementing a solution to the patient identification problem, which confirm similar findings from other developing countries [47] are discussed below.

6.1. Technical Challenges

A first barrier in establishing a solution on a national level is the fact that even developing countries may have at least one HIS in place and are likely to be already treating patients using WHO guidelines. Therefore, any candidate solution must provide continuity in health information management [41]. In addition, most current and envisaged HIS solutions appear to rely on reasonable power availability and especially on suitable networking capability (via peer networks but also the Internet) e.g. for 'cloud' storage and processing, aiming towards *pervasive healthcare* [2, 51] based on the Internet of Things (IoT) paradigm, employing e.g. Wireless Sensor Networks [29]). The literature review performed reinforced by the findings of this research reveal that unfortunately power and Internet infrastructure is currently not reliable in developing countries.

Still, technical challenges may be the easiest to overcome compared to the hurdles further described below, which require time and willingness to change mentalities and policies.

6.2. Social Challenges

Due to privacy concerns, people might not want to share their information (e.g. trust issues). Building a system that can always identify individual patients is thus a major social challenge, even if some people already share their information using smart cards, passports or other identification technologies. One must also note that in developing countries some individuals live completely 'off the grid', i.e. without any interaction to the world of technology. General purpose identification technologies exist; e.g., many countries now issue Machine Readable Passports (MRP) for international travel, collect biometric identification using fingerprint scanners, and use facial recognition software, so as to be able to identify people. However, whether these are useful or feasible in developing countries' healthcare systems context remains a question and matter for further research.

6.3. Cultural Challenges

In some developing country cultures, it is forbidden for some members of the family to share their information. Therefore heads of the family provide their contact information, instead of the individual. In countries where women are not even allowed to go to hospital for child birth, this issue may become a significant impediment as giving personal biometric identification information may be seen as a threat. In other cases, people do not even allow an 'outsider' (i.e. healthcare professional) to advise any member of their group (e.g. tribe). The matter of patient identification in such areas must be approached with caution as it may not only lead to erroneous results but actually pose a threat to the health workers.

6.4. Ethical Challenges

In the introduction of new systems and associated software there are always privacy and security concerns. In HIS, this typical problem translates into hacking, identity theft and unauthorized access and alteration of data, facilitated by making EHRs universally available (a goal and major benefit of modern HISs) [14, 38]. Another important aspect relates to improper use of data, such as information being shared with various organizations / government. This is especially true for HIS and serious diseases such as the treatment and medication of TB and/or HIV infected/AIDS patients, as inappropriate use of this information may create significant prejudice and inequity in the workplace and society in general. Thus, 'infoethics' [26] must be rigorously observed, which is not a trivial task, especially in the socio-economic and cultural context of many developing countries.

7. Specific Healthcare Information Systems Requirements in Context

In view of the above-described context, this research can define a set of specific architecturally significant requirements [11] contributing to WHO's HIS design framework [41] for a sustainable HIS, which could help overcome the barriers identified in the study, as follows:

- i) consistency: HIS design should be underpinned by a set of consistent and integrated set of standards (which currently does not seem to exist);
- ii) interoperability: capacity to access, exchange and update patient information irrespective of physical location, to enable collaborative and ubiquitous healthcare [2, 35, 36, 51];
- ii) availability: resilience during power outages and especially lack of network connectivity;
- iii) integrity: ability to cope with patients unable to provide their details or past medical history records;
- iv) security: capacity to protect patient-identifying information;
- v) scalability: consistent behaviour and performance irrespective of patient numbers.

The above-mentioned list of requirements is intended to constitute a high-level supportive platform for further HIS research especially in developing countries and as such is not further elaborated upon in this paper (as this would be outside its proposed scope).

8. Conclusion and Further Work

Notwithstanding limitations in relation to the size of the database and number of persons interviewed, the research work performed in this paper has illustrated that currently, even in healthcare facilities with an HIS implementing mainstream information representation standards, multiple health records of individual patients may occur owing to various intentional or accidental causes. Even if manual or semi-automated data cleansing was affordable (and feasible) so as to find all duplicate identifiers *post factum* (e.g. for reporting purposes), this situation would still affect patient security unless promptly and regularly performed (which unfortunately is not currently the case). The lack of uniformity of the standards (and their versions) underlying typical HISs compounds the problem.

The authors have systematised the patient identification issues found, followed by identifying the likely root causes and subsequently attempting to define a high-level list of the most relevant HIS requirements that could help alleviate the problem at hand.

The unwanted effects of patient identification go far beyond individual patients or healthcare facilities. Thus, wrong decisions can be made by policy makers based on inaccurate reports from treatment centres, which can result in insufficient budgeting, wasted human effort, sub-optimal resource allocation, improper policies and thus incorrect action for long term (e.g. disease eradication) and short term (e.g. pandemics) healthcare problems.

The paper aims to contribute through its findings to future research in the design and implementation of a new generation of IoT technologies-enabled, 'sensing' HIS [51] that will help fulfil the promise of pervasive healthcare, by emphasizing the acute necessity to solve non-trivial issues specific to developing countries - where the most significant and critical healthcare battles have been, are and most likely will be fought in the foreseeable future.

Further work aims to further validate the findings by gathering additional primary and secondary data via interviews, surveys and other suitable mechanisms.

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