Internal Hospital Crises and Disasters in The Netherlands, 2000-2020

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Abstract

Study Objective

Internal hospital crises and disasters (IHCDs) occur with regularity and require the attention of emergency managers, hospital administrators, and physicians to prepare their hospitals accordingly. Information on the frequency and types of IHCDs is limited and we aim to characterise the disasters that occurred in Dutch hospitals from 2000 to 2020.

Methods

A retrospective search of news articles utilizing the LexisNexis database, Google, Google News, PubMed and EMBASE between 2000 and 2020 was conducted. All articles mentioning the closure of a hospital department in the Netherlands were analysed.

Results

A total of 134 IHCDs were identified in a 20-year time period. Of these IHCDs, there were 96 (71.6%) emergency department (ED) closures, 76 (56.7%) operation room (OR) closures, 56 (41.8%) evacuations, 26 (17.9%) reports of injured persons, and 2 (1.5%) reported casualties. Cascading events of multiple failures transpired in 39 (29.1%) IHCDs. The primary causes of IHCDs were Information and Communication Technology (ICT) failures, technical failures, fires, power failures, and hazardous material danger. An average of 6.7 IHCDs occurred per year and a comparison between initial and latter decade intervals showed an increasing trend with a rate ratio (RR) of 3.2. ICT failures have also significantly increased in this same interval with a RR of 14.2.

Conclusion

IHCDs occur frequently in the Netherlands and have marked effects on hospital critical care departments; EDs in particular. Significantly increasing numbers of IHCDs and ICT related IHCDs per year indicate a worrying trend requiring attention by emergency managers and hospital administrators.

Introduction

Emergency medical services and the emergency departments (EDs) within hospitals are viewed as the community based resources responsible for the initial response towards any type of disaster[1]. These facilities are generally well prepared for community-based disasters. However, they are less prepared for hospital based events that threaten the daily functioning of the organization. [2] Internal hospital crises and/or disasters (IHCDs) combine two different concepts. An internal hospital disaster refers to a sudden onset event that disrupts the everyday, routine services of a facility itself, and may or may not be associated with an external, or community wide event[2]. An internal crisis refers to an urgent threat to the wellbeing of patients, and/or the continuity of hospital services that must be addressed under conditions of deep uncertainty[3–5]. Globally, IHCDs seem to occur with regularity with reported causes including

natural disasters[6, 7], toxic substances[8], structural failure[9], fires[10, 11], flooding[12], and terrorist threats[13].

The Netherlands has a modern healthcare system with effective primary care and specialized acute and critical care facilities, that are highly ranked and analogous in quality and access to other western countries [14]. The Netherlands has been assessed to be the 12th most exposed country in the world and the most vulnerable country in Europe to natural disaster due to significant below sea-level land area and an increasing prevalence of strong storms [15]. However, a sound infrastructure and healthy finances offset these hazards making the effective rank 49th worldwide [15]. Between 2000 and 2020, the Netherlands has suffered from 17 natural hazard-induced disasters and 5 technological-induced disasters [16]. The most common disasters were storms (10), extreme temperature (7), fire (2), explosion (1), flooding (1), and railroad accidents (1). These events varied greatly in magnitude, but collectively resulted in 2,439 deaths and substantial financial losses[16].

Nonetheless, little is known about the impact of those widespread disasters on hospitals and healthcare systems, and on and the frequency and type of IHCDs. Furthermore, IHCDs are scarcely reported in medical literature as hospitals rarely report on single events. Contrastingly, newspapers, news press releases and other grey literature often publish valuable information on these incidents. We have reviewed the IHCDs from 2000 to 2020. Our analysis of these events aims to increase hospital disaster preparedness and thus improve business continuity in times of crisis.

Materials And Methods

Setting:

The study took place in the Netherlands, a Western European country consisting of 17.4 million people [17]. The Netherlands maintains a high standard of care with 83 hospitals with an ED and ICU, providing 24-hour emergency care and 4 additional locations open during the day/evening hours [18], affording a total of 1,989,746 ED visits in 2012[19]. The hospital network is further subdivided into 8 academic hospitals, 26 teaching hospitals that provide complex patient care[20], and 53 general peripheral hospitals. Fourteen hospitals serve as level 1 trauma centres organized into 11 trauma regions [21]. The total number of hospitals has decreased over the years due to mergers and centralization of emergency care from 107 acute care hospitals in 2003 to the current 87 in 2020 [18]. Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this study. The institutional review board of VieCuri Medical Centre, Venlo, the Netherlands, approved this research project (#439).

Search:

Public search engines (PubMed, Medline, Google, Google News) and the LexisNexis database were used to search for articles and press releases in the Netherlands between January 1, 2000 and December 31, 2019. The search terms “hospital,” “closed,” “ICU,” “ED,” “department,” “failure,” “fire,” and “evacuation” and their synonyms were combined with Boolean operators resulting in around 50,000 headlines reviewed.

Articles were only included in this study if one or more Dutch hospital departments or intervention units (ORs, diagnostic rooms/equipment) suddenly and unexpectedly had to be closed, were evacuated and/or if injured persons needed treatment. Events were excluded if inpatient or critical care departments were unaffected or if the event did not take place at a fully-fledged hospital (containing an ED and ICU). Partial closures or evacuations were excluded. Hospital or ED closures due to overcrowding, staffing shortages, staff strikes, nationwide epidemics, medical malpractice, and insect manifestations were also excluded.

Event Classifications:

Each event was categorized based on cause of hospital department closure. In cascading events, the events were sequentially noted with the initial instigating event considered the primary cause utilized in our analysis. Each of the events were classified into technical failures, ICT failures, fires (internal and external), power failures (internal and external), hazardous materials, structural failures, utilities failures, loss of medical gasses, hydrometeorological, and security and violence). Appendix 1 details exact classification definitions.

Analysis:

Data was extracted and independently characterised by 2 of the authors (V.W.K. and D.G.B.) When discrepancies could not be resolved, 3 other reviewers made the final judgement (M.G.J.V., N.A.L.R.P., M.I.G.). For each included “incident,” specific searches utilising key terms from the included articles resulted in 3,684 total articles. All possible data was extracted and aggregated into a database and hospital demographics regarding bed size and trauma level were ascertained from the Dutch Public Healthcare Database [18]. Fisher’s Exact Tests were performed for comparisons between the first decade (2000–2009) and latter decade (2010–2019) of the dataset. Statistical significance was represented by the risk ratio (RR) and its 95% confidence interval (CI). Calculations were performed using a statistical package program (SPSS version 24, IBM, Chicago, IL).

Results

During the study period from January 1, 2000 to December 31, 2019, 134 IHCDs were identified (mean 6.7/ year) in 61 different hospitals. Two IHCDs were found with the PubMed searches and all IHCDs were found with media searches. Figure 1 depicts the number of incidents per year and risk of IHCD occurrence per hospital, and shows an increasing trend. This resulted in an average risk of 6.9%, and ranged from 2.8% in 2000 to 16.1% in 2019. A linearly increasing trend in IHCDs was noted (Fig. 1) with a mean rate of 10.2 IHCDs per year in the latter 10 years (2010–2019), compared to 3.2 IHCDs per year in the initial 10 years (2000–2009) (RR = 3.2; 95%CI 2.1 to 4.9). Every Dutch province experienced an IHCD with the majority of IHCDs occurring in the more populous regions of North Holland 33 (24.6%) and South Holland 32 (23.9%) with an average of > 10 hospitals within 20 km distance [22]. All types of hospitals were affected by IHCDs including academic hospitals and level 1 trauma centres. The general hospital characteristics are depicted in Table 1.

Table 1
Hospital characteristics of ICHDs occurring in Dutch hospitals, 2000–2020.

Characteristics and Categories	Total number of Incidents, %, N = 134
Type of Hospital	
Academic	20 (14.9)
Teaching	68 (50.7)
peripheral	46 (34.3)
Trauma Level	
1	31 (27.4)
2	74 (55.2)
3	29 (21.6)
Hospital Bed Size (No. of Beds)	
< 400	34 (27.4)
400–600	39 (29.1)
> 600	61 (45.5)

Of the IHCDs, 108 (80.6%) were isolated internal IHCDs, while 26 (19.4%) were combined internal and external events that eventually affected the internal functioning of the medical facility. The primary causes of IHCDs were ICT failures (n = 33; 24.6%), technical failures (n = 29; 21.6%), fires (n = 24; 17.9%), power failures (n = 21; 15.7%), hazardous materials (n = 15; 11.2%), structural failures (n = 5; 3.7%), meteorological (n = 4; 3.0%), and security and violence (n = 3; 2.2%).

Event cascades were prevalent in 39 (29.1%) IHCDs, resulting in multiple failure type classifications being applied to a single IHCD (Table 2). Often occurring cascades include internal power failures resulting from technical failures after external power outages (9; 23.1%), ICT failures after power outages (6; 15.4%), technical failures leading to fire (4; 10.3%), technical failures leading to internal power outages (4; 10.3) and technical failures leading to the release of hazardous materials (3; 9.0%). Cascading events have resulted in a total of 193 failures which are summarised in Table 2. Cascading events were especially evident in internal power failures as they accounted for 3.0% of primary failures, compared to 11.9% of total failures. Fire and power failure sources were also noted as they can either arise from within the hospital terrain, or externally from an outside source or provider. Of the 29 fires, 27 (93.1%) were internal fires and 2 (6.9%) were external fires. Internal power failures affected 19 (51.4%) and external power failures 18 (48.6%) events.

Table 2
Characteristics of IHCDs occurring in Dutch hospitals, 2000–2020.

Characteristics and Categories	**Primary Failures, %, N = 134**	**Total Failures, %, N = 193**
Technological Failure	29 (21.6)	45 (23.3)
ICT Failure	33 (24.6)	39 (20.2)
Internal Fire	22 (16.4)	27 (14.0)
External Fire	2 (1.5)	2 (1.0)
Internal Power Failure	4 (3.0)	23 (11.9)
External Power Failure	17 (12.7)	18 (9.3)
Hazardous Materials	15 (11.2)	19 (9.8)
Structural Failure	5 (3.7)	7 (3.6)
Utilities Failure	0 (0.0)	4 (2.1)
Loss of Medical Gasses	0 (0.0)	2 (1.0)
Meteorological	4 (3.0)	4 (2.1)
Security & Violence	3 (2.2)	3 (1.6)
Type of IHCD	**Count, %, N = 134**	**Count, %, N = 39**
Internal	108 (80.6)	
Combined	26 (19.4%)	
Cascading Events	39 (29.1)	
External Power Failure: Technical Failure : Internal Power Failure		9 (23.1)
ICT Failure After Power Failure		6 (15.4)
Technical Failure leading to Fire		4 (10.3)
Technical Failure leading to Internal Power Failure		4 (10.3)
Technical Failure leading to Hazardous material incident		3 (9.0)

Changes in the failure trend were compared between the initial and latter decade for each IHCD classification. Primary ICT failures (2000–2009, n = 1, 2010–2019, n = 32) showed a significant trend (RR = 14.2, p = 0.001, Fisher's Exact Test), while all other failure types did not show significant differences. Figure 1 shows the absolute number of IHCDs and the total number of ICT failures with linear regression. The total number of IHCDs remains stable, whilst the addition of ICT failures explains the increasing rate

of IHCDs. The increase remained substantial even after correction for the association of cascading events (RR of 14.2 versus 11.2). Out of 134 IHCDs, a total of 96 (71.6%) ED closures, 76 (56.5%) operation room (OR) closures, and 56 (41.8%) evacuations (Table 3). Of the 56 total evacuations, in 37 (66.1%) patients/staff/visitors were displaced internally, 12 (21.4%) IHCDs caused the evacuation of patients externally, and in 7 (12.5%) events patients were evacuated both internally and externally. These IHCDs caused major disruptions in the hospital critical care departments, with 110 events (82.1%) having ED involvement with either the ED directly being affected. Of these cases, the ED was directly affected by the IHCD in 96 IHCDs (87.2%) and activated for the care of injured patients in 26 IHCDs (23.6%). Injured persons occurred in 26 (17.9%) of the incidents and in 2 (1.5%) cases there were casualties (2 total casualties).

Table 3
Departmental effects, evacuation locations and injuries of IHCDs occurring in Dutch hospitals, 2000–2020.

Characteristics and Categories	Total, %, N = 134	Total, %, N = 56
ED Involvement	110 (82.1)	
ED Presentation Stop	96 (71.6)	
OR Stop	76 (56.7)	
Evacuations	56 (41.8)	
- Internally		37 (66.1)
- Externally		12 (21.4)
- Combined		7 (12.5)
Injuries	24 (17.9)	
Casualties	2 (1.5)	

Discussion

Hospitals, and their EDs in particular, serve an important function in the community as wardens of public health in times of crisis and disaster[23]. IHCDs can directly cause physical harm and the sudden closure of a hospital or ED may force the diversion of patients to distant hospitals where patient records are lacking [24]. We have shown that hospital and departmental closures have occurred 134 times in the Netherlands with an increasing trend across a 20-year study period. Natural disasters rarely occur in the Netherlands and did not cause an IHCD in our dataset, with the exception of 4 incidents caused by inclement weather. Cascading events of multiple sequential failures occur 29.1% of the time where ultimately a hospital or department becomes disabled. EDs are often involved both directly and indirectly with 71% of IHCDs incurring an ED closure.

ICT Failures are an Increasing Trend:

The 20-year-period studied showed an average of 6.7 IHCDs per year. Alarmingly, we have shown that the incidence of these events is increasing and are in large part explained by the increase in ICT failures. This should not come as a surprise considering that the healthcare sector has seen increases in the use of digital technologies in communication, diagnostics, and treatment applications[25]. The frequent occurrence exposes a weakness in hospital preparedness and business continuity that must be addressed. Malfunctioning of backup servers, impossibility of quickly reverting to paper dossiers at an instant's notice and general lack of training were problems mentioned in the news articles. While our search did not uncover any reports of cyberattacks on hospital networks, there is previous experience with ransomware affecting hospital networks in the United Kingdom resulting in multiple, prolonged ED closures [26]. The increasing trend in ICT disturbances make cybersecurity and digital continuity issues that should be prioritized in hospital disaster preparedness[27]. Furthermore, our data corroborates a recent Dutch governmental report detailing an increasing trend of hospital ICT failures and their potential impacts on patient safety[28].

Cascading Events

Hospitals are complex organisations and structures with convoluted interrelated systems [29]. Hospital resilience in mitigating internal crises appears to be habitually challenged by multiple consecutive failures in the form of cascading events. Nearly a third of IHCDs express this trend (Table 2). Hospitals customarily seem to be able to absorb one "hit" to their internal infrastructure, such as a simple external power failure where the auxiliary power seamlessly starts and the hospital continues to function. Conversely, if somewhere in that succession of events an additional failure, such as a technological failure (i.e. short circuit) occurs hindering the emergency power sources, a hospital fails to be able to provide lifesaving services. Power outages often led to failures involving the computer networks, and technological failures also tend to lead to equipment malfunctions that in turn lead to fires and hazardous material releases. Knowledge of these predominantly occurring sequential events are beneficial for attenuation of safety checks in disaster preparation plans. Examples would include frequent auxiliary power tests, training of personnel to bypass problems with power and the creation of emergency procedure guides in the face of ICT failure.

Hazardous Materials

Hospitals are fertile grounds for disaster as they are packed with flammable gasses, toxic substances, biological sources and radioactive materials. Patients injured by these same types of substances ideally present to the ED in a decontaminated state. However, this is not always the case, endangering hospital employees or prompting evacuation. Hospital evacuations occurring from both threatened and actual hazardous material exposure, or release typically come with little warning or time to prepare, often occurring in EDs [30]. Between 1971 and 1999, 18% of U.S. hospital evacuations were due to hazardous materials[31]. Comparatively, we found 19 incidents occurring in the Netherlands in the past 20 years, each necessitating evacuation (33.9% of total evacuations). High consequence infectious diseases and emerging infectious diseases such as the 2019 Novel Coronavirus (COVID-19), also pose significant risks

to hospitals and EDs, where hospitals need be able to safely treat infected individuals while maintaining surge capacity[32]. Unprepared hospitals receiving these types of patients lead to dangerous situations, panic and eventual evacuations. Our dataset entails 2 ED closures lasting several hours due to possible Ebola viral disease infection. Unpreparedness and no prior notice of patient arrival caused considerable delay while the emergency services scrambled to collect appropriate protective equipment and protocols.

Hospital Characteristics

Our data has shown that hospitals in the Netherlands are susceptible to sudden closure due to IHCDs irrespective of trauma level or academic specialties. The acute closure of academic hospitals and level 1 trauma centres places a large burden on emergency medical services by increasing the travel distance to an appropriate medical centre, or the need to transport severely injured patients to underprepared centres. Critical access hospital closures would exacerbate these problems in more rural settings. Closer hospital proximities and multiple trauma centres in larger urban areas make this problem less evident.

Advice to ED and Hospital

Hospitals shelter a high number of vulnerable and dependent individuals, sustained by high densities of medical and support staff. Risks and hazards to potential disasters must be made apparent and planned for. As part of a hospital's accreditation in the Netherlands, a hospital disaster plan must be available, and the staff must be trained to act in extenuating circumstances to both external and internal sources of disruption [33, 34]. The most common types of internal disaster plans only encompass computer system failures, power failures, and fires [35]. We have enumerated the possible types of IHCDs having transpired in the Netherlands, which can be extrapolated and applied as potential hazards to the majority of modern healthcare facilities in developed countries. If these internal disaster plans are revised in line with our findings, this will have the potential to improve hospital recovery in times and possibly prevent unnecessary closure. Hospital management officials and emergency physicians should attenuate their hospital disaster plans based on the incidents we have enumerated to prevent future closure. Creation of generic crisis response templates based on the most common disaster and cascading events will allow hospital coordinators to create trainings to show employees how the various hospital systems are organised and how to respond to specific failures [29]. Training of hospital staff, notably ED staff, should occur frequently to ensure seamless activation of disaster plans. Furthermore, a unified body that registers IHCDs nationally and that acts as a hospital disaster preparedness expertise centre would be a valuable medium where learned lessons can be shared with other medical centres.

Limitations:

There are several limitations in our search method that may have led to under ascertainment of total incidents. Due to the subjective nature of press and news releases, bias towards sensationalistic and newsworthy events may have arisen, leaving out smaller and less impactful incidents. However, we deem it likely that events in which a department had to be closed urgently would have made the news. Underreporting of incidents may have occurred in earlier years due to inaccessibility of articles and

decreased number of reporting news outlets (i.e. now more online news articles than print versions). Furthermore, we have only included acute care hospitals and our results cannot be applied to specialised clinics and hospitals. Potentially valuable information on the exact duration of department closure was not available in all incidents. Nonetheless, the sources and databases used are the best available. This is to our knowledge the first study utilizing this search methodology to characterize IHCDs, but can be applied to other regions in the world. Therefore, our classification system of IHCDs from news sources has not been validated. This study was geographically limited to the Netherlands, though we believe that the incidence and failure types to be applicable to all modern hospitals with the exception of natural disasters more common in other regions of the world.

Conclusion

Healthcare Facilities are vulnerable with IHCDs regularly occurring in the Netherlands and have marked effects on hospital critical care departments; EDs in particular. An increasing trend in incidence is seen, explained by the significant increase of ICT failures. Cascading events of multiple failures transpire nearly a third of the time, limiting the ability of a hospital to stave off closure due to failure. Emergency managers should attenuate their hospital disaster plans based on the incidents we have enumerated to prevent future closure. Hospital staff should receive regular training to respond to IHCDs.

Abbreviations

CI
Confidence Interval
COVID-19
2019 Novel Coronavirus
ED
Emergency Department
ICT
Information and Communications Technology
ICU
Intensive Care Unit
IHCD
Internal Hospital Crisis and Disaster
OR
Operating Room
RR
Rate Ratio
U.S.
United States

Declarations

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The institutional review board of VieCuri Medical Center, Venlo, the Netherlands, approved this study (#439).

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Please contact author for data requests.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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AUTHORS' CONTRIBUTIONS

DGB conceived the study. DGB and VWK designed the study. FO provided statistical advice on the study design; all authors approved the study protocol. Data was extracted and independently characterised by 2 of the authors (V.W.K. and D.G.B.) When discrepancies could not be resolved, 3 other reviewers made the final judgement (M.G.J.V., N.A.L.R.P., M.I.G.). Data were analyzed by VWK with the assistance of DGB and FO. VWK drafted the manuscript, and all authors contributed substantially to its revisions. All authors read and approved the final version of the manuscript.

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Not applicable.

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Netherlands. ECTHT is trauma surgeon and medical disaster preparedness officer at Radboudumc medical center in Nijmegen, the Netherlands. He also holds the position of HEMS physician. AB is professor at the department of political science at Leiden University, Leiden, the Netherlands.

Dissemination declaration: These results will be shared with the Crisis coordinators of each hospital to prevent further internal hospital disasters and/or crises.

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Figures

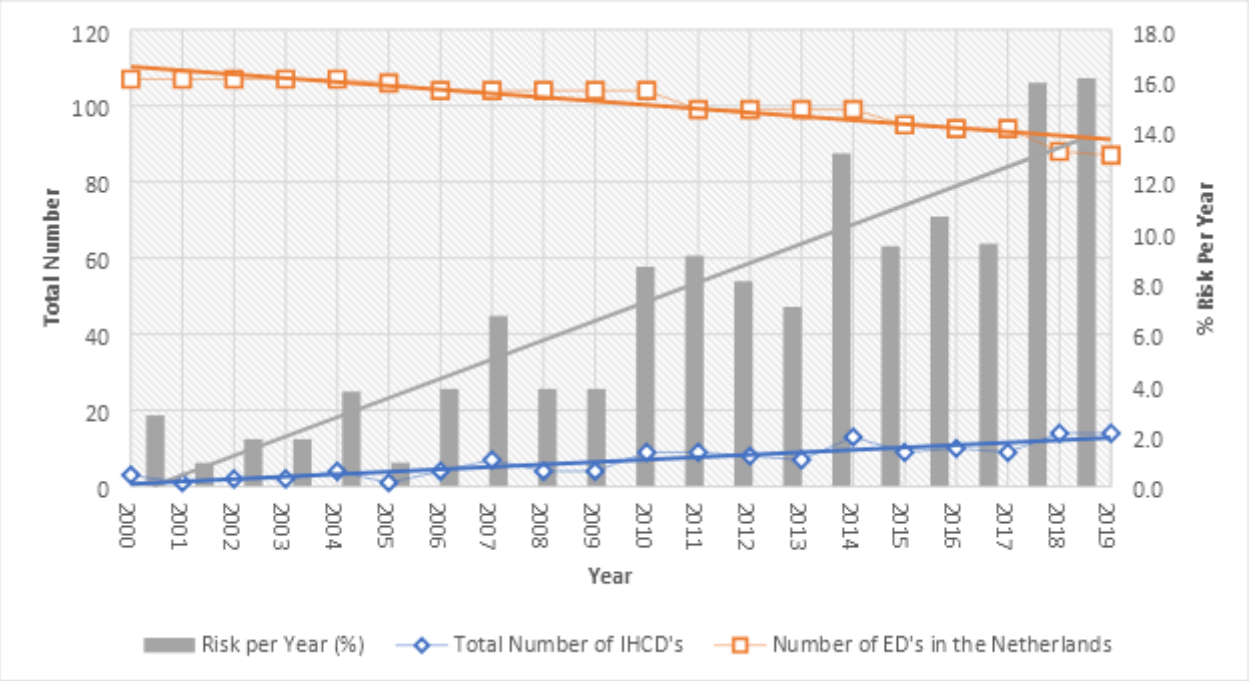

Figure 1

Number and risk of ICHDs plotted against the number of EDs in the Netherlands, 2000-2020. X-axis depicts the years 2000-2020. Left Y-axis depicts the total number of ICHDs per year. Right Y-axis depicts the calculated risk (percentage) per hospital per year to be confronted with an ICHD. Orange boxes depict the number of EDs per year in the Netherlands. ABBREVIATIONS ICHDs: Internal Hospital Crises and Disasters EDs: Emergency Departments

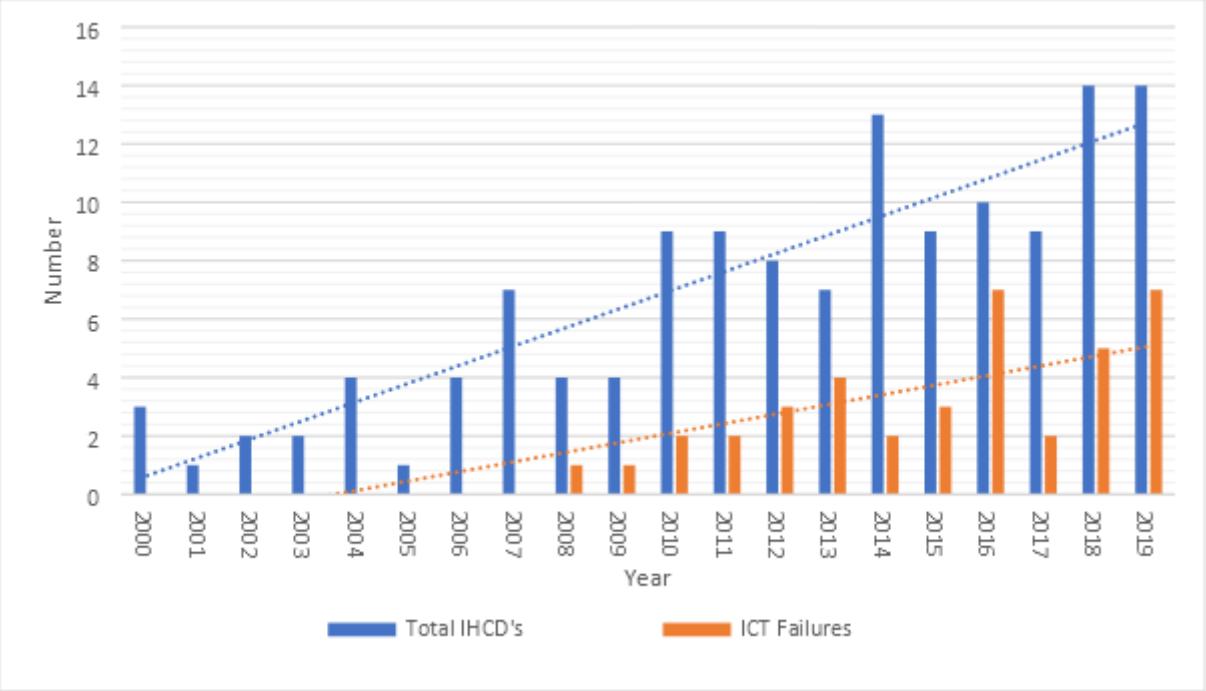

Figure 2

Per year trends of ICHDs and primary ICT failures with linear regression, 2000-2020. X-axis depicts the years 2000-2020. Left Y-axis depicts the total number of ICHDs per year. ABBREVIATIONS ICHDs: Internal Hospital Crises and Disasters ICT: Information and Communication Technology

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- ResearchChecklist.doc
- APPENDIX1.docx