



Decline in mortality with the Belize Integrated Patient-Centred Country Wide Health Information System (BHIS) with Embedded Program Management

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ARTICLE INFO

Article history:

Received 26 November 2012

Received in revised form 9 May 2013

Accepted 1 June 2013

Keywords:

Health information system

Electronic health records

Electronic medical record

eHealth

Electronic clinical decision support

Health outcomes

Developing country

ABSTRACT

Background: Belize deployed a country-wide fully integrated patient centred health information system with eight embedded disease management algorithms and simple analytics in 2007 for \$4 (Cad)/citizen.

Objectives: This study evaluated BHIS uptake by health care workers, and pre and post BHIS deployment mortality in selected areas and public health care expenditures.

Methods: BHIS encounter data were compared to encounter data from required Ministry of Health reports from licensed health care entities. De-identified vital statistics death data for the eight BHIS protocol disease domains and three non-protocol domains were compared from 2005 to 2011. Belize population data came from the Statistical Institute of Belize (2005–2009) and from Belize census (2010) and estimate (2011). Public health system expenditures were compared by fiscal years (2000–2012).

Results: BHIS captured over 90% healthcare encounters by year one, 95% by year two. Mortality rates decreased in the eight BHIS protocol domains (each 2005 vs. 2011, all $p < 0.02$) vs. an increase or little change in the three domains without protocols. Hypertension related deaths dropped from 1st cause of death in 2003 to 9th by 2010. Public expenditures on healthcare steadily rose until 2009 but then declined slightly for the next 3 years.

Conclusion: For modest investment, BHIS was well accepted nationwide and following deployment, mortality in the eight BHIS disease management algorithm domains declined significantly and expenditures on public healthcare stabilized.

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1. Introduction

In 2007, Belize deployed a country-wide integrated patient centred health information system, the Belize Health Information System (BHIS) [1,2], that incorporates elements of electronic medical records, electronic health records, patient

management algorithms, health system management, supply chain management, business intelligence and analytics that uses a single graphical user interface (see Figs. 1 and 2 for typical screen shots). The BHIS has embedded disease prevention/management algorithms that help clinicians make evidence based care decisions in eight health domains (Table 1). Full integration supports cross encounter analyses,

Abbreviations: BHIS, Belize Health Information System.

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<http://dx.doi.org/10.1016/j.ijmedinf.2013.06.003>

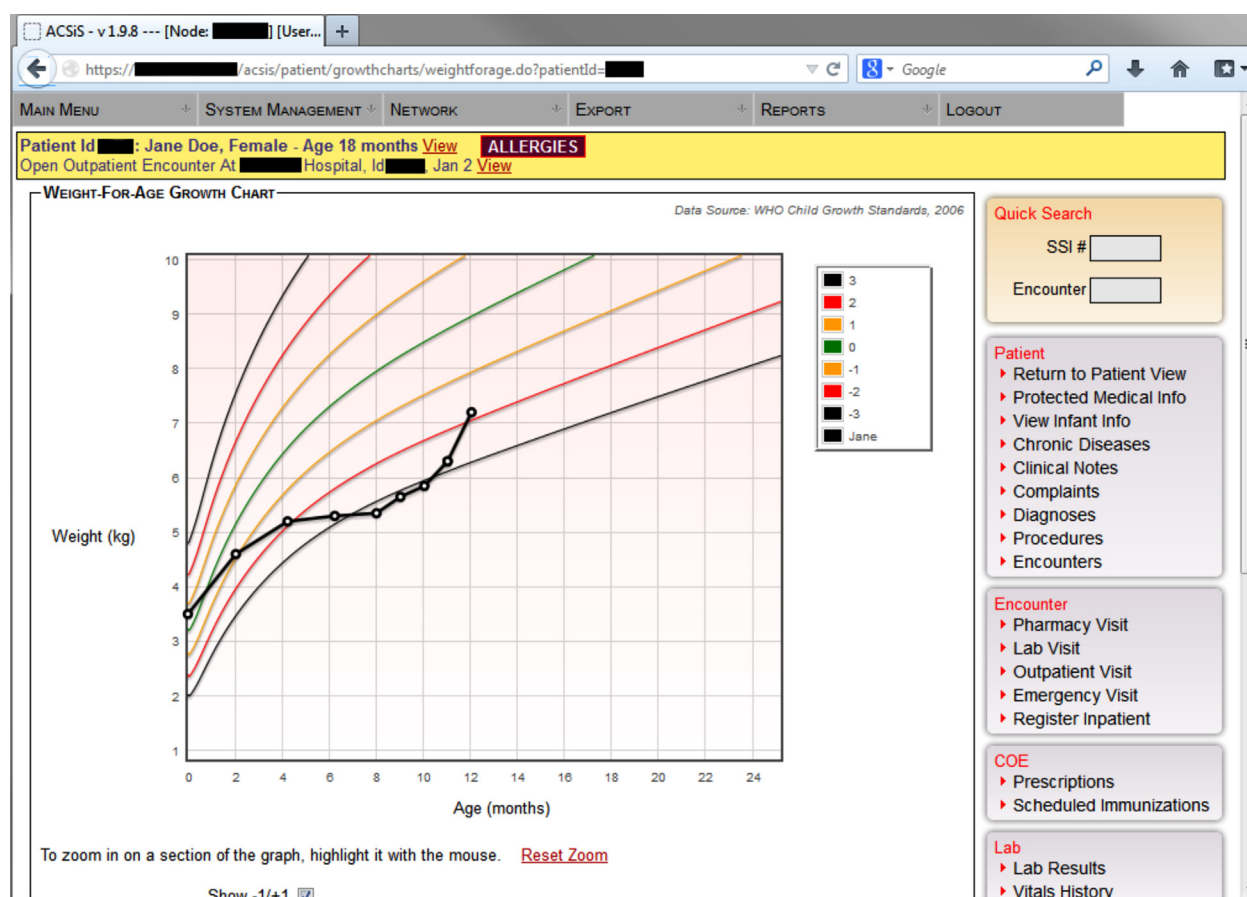


Fig. 1 – BHIS screen shot illustrating infant growth curve screen view for “Jane Doe”. Hospital and other identifying information have been omitted.

i.e. determination of the percentage of pneumonia patients who did or did not fill an outpatient antibiotic prescription and how this affected hospitalization rates by region, by demographics, by programme.

Health information is collected at the time/place of interaction between any health care provider and a person seeking health services with all earlier patient encounter data available at the time of the current encounter (Fig. 3). Thus a clinician, at the time of a new patient encounter, has all past information available no matter where previously seen in the country. If the patient's age or problem falls within one of the eight health domains, the clinician is prompted by test menus or medication choices to make evidence based care decisions (see Fig. 2 for screen shot prompt for MMR vaccine that should have been given at 12 months in this 18 month old child seen in outpatient clinic).

1.1. BHIS background

Belize is a small middle income developing country; population in 2010 of 312,698 [3] and gross domestic product per capita of \$8400; an increase from \$6800 in 2005 [4]. In 2010, 5.2% of the gross domestic product was spent on health care [5] which is predominately public with only 6% private sector.

Healthcare in Belize involves a large public system, a small private system and a smaller volunteer system. In 2009, Belize had 8.3 physicians and 19.6 nurses or midwives per 10,000 population [5]; 1.35 hospital beds per 1000 population (1.14 public; 0.59 private or volunteer); 0.054 diagnostic imaging equipment per 1000 population (0.04 in public sector; 0.016 in private or volunteer) and 0.023 clinical labs per 1000 population (0.03 public; 0.012 private or volunteer) [6]. Only one of the seven public hospitals, the Karl Huesner Memorial Hospital, provides tertiary care including dialysis; adult, paediatric and neonatal intensive care; and cardiac surgery. More than 95% of outpatient encounters of all types are at Ministry of Health Facilities. Many of the clinicians that provide services at the private facilities also provide services in Ministry of Health facilities. Rural healthcare outposts (with only basic services) are staffed chiefly by Cuban Physicians under contracts between Government of Belize and Government of Cuba.

The BHIS began as a small part of the Belize Health Sector Reform of 2004, with major deployment starting mid 2007. The software used by the BHIS is based upon free, open source software elements, including Linux™ operating system, PostgreSQL™ database system and Java™ programming environment. The system was developed by an industrial process improvement company, Populus Global Solutions, Inc.

ACSiS - v1.9.8 --- [Node:] [User:] +

https://.../acsis/coe/patient/encounter/immunizations.do?patientId=...&encounterId=...

MAIN MENU SYSTEM MANAGEMENT NETWORK EXPORT REPORTS LOGOUT

Patient Id: Jane Doe, Female - Age 18 months [View](#) **ALLERGIES**

Open Outpatient Encounter At Hospital, Id, Jan 2 [View](#)

Current Encounter: Id - Facility: Hospital [View](#)

Type: Outpatient, Started: Jan 2, 2013 2:09 PM

IMMUNIZATION HISTORY

NATIONAL IMMUNIZATION SCHEDULE (EPI)	TYPE OF VACCINE	AGE	DATE OF IMMUNIZATION	LOT/EXPIRY	
At Birth	BCG	1 days	Nov 3, 2011	Serum Institute of India / EUSIN5016 / May 30, 2012	Edit
2 Months	OPV - 1	8 weeks	Jan 3, 2012	Novartis / 102206 / Feb 28, 2012	Edit
	Pentavalent - 1	8 weeks	Jan 3, 2012	GlaxoSmithKline Biologicals (Belgium) / P0170/SBP / Aug 31, 2012	Edit
4 Months	OPV - 2	4 months	Mar 13, 2012	Novartis / 113911 / Feb 28, 2013	Edit
	Pentavalent - 2	4 months	Mar 13, 2012	GlaxoSmithKline Biologicals (Belgium) / P0204/ SBP / Sep 30, 2012	Edit
6 Months	OPV - 3	10 months	Sep 30, 2012	Novartis / 113911 / Feb 28, 2013	Edit
	Pentavalent - 3	6 months	May 11, 2012	GlaxoSmithKline Biologicals (Belgium) / P0204/ SBP / Sep 30, 2012	Edit
	Influenza	6 months	May 11, 2012	Sanofi Pasteur / UH4178CA / Jun 30, 2012	Edit
12 Months	MMR - 1				Administer Record Past

Encounter
[Return to Encounter](#)

Fig. 2 – BHIS screen shot illustrating an immunization prompt for “Jane Doe” who has missed her 12 month measles mumps and rubella vaccine. Hospital clinic and identifying information have been omitted.

(formerly Accesstec, Inc.), Fredericton, New Brunswick, Canada. The software was built through joint application development with Belizean and Canadian health professionals on all planning teams. Each task group included lay members ensuring community input. Critical design requirements included making the healthcare documentation processes easier/quicker than prior to the BHIS, e.g. minimizing data entry time by avoiding redundancy and use of templates, having data entry screens mimic previous paper forms to simplify user learning curves and ensuring all patient data be readily available in real time. Every health care worker makes their own entries; no data entry clerks, no scanning of orders, no hand written chart entries. The incentives to use the system are ease of access and ease of use with simple learning curve, more effective use of time as all individual patient information gathered in one place, minimization of need to re-document, i.e. limitation of redundancy and no cost to the user. No financial incentives beyond free software were used. The software choices ensured no annual software license fees, no fees for system deployment at new facilities or with registration of new users and limited the hardware costs for new sites.

Hardware requirements were made simple with few limitations for equipment that could use the software, i.e. an appliance model. The number and sophistication of servers, routers and switches was also kept modest. The BHIS is linked by a combination of fiberoptic lines and Internet connections including wireless. As hurricanes are a common problem, local systems are supported with generator back up. When able, the local system then reconnects to the full system to update records with any interim visit data collected locally during the storm and its aftermath. Despite Belize having been struck by five major hurricanes and serious tropical storms (<http://consejo.bz/weather/storms.html>) in the past 4 years, the system has always been available locally.

Development costs, including hardware, were approximately \$4 (Cad) per Belizean citizen, i.e. \$1.2 million(Cad) with approximately 31% spent on software development 58% on design requirement development including consensus building among Belizean healthcare and community stakeholders and 11% on hardware. Annual costs for ongoing support of the BHIS are approximately \$3(Can) per Belizean citizen.

BHIS privacy is assured with only role specific access to appropriate elements, close daily monitoring of unauthorized use and restricted special access for high profile patients.

Table 1 – Eight domains with evidence based prevention/management guidelines incorporated into the BHIS and the selected causes of death for inclusion in the mortality rate analyses.

	Domain	Protocol areas	Selected causes of death
1.	Neonates and Infants up to one year	Neonates: - Examination, monitoring, assessment and management Infants: - Immunization protocols - Schedules for preventative care visits for children to assess nutrition, growth and development - Workup and treatment for acute respiratory or acute gastrointestinal infections	- Death involving problems of birth, nutrition, dehydration, acute respiratory or acute gastrointestinal infection, not involving HIV.
2.	Children 1 to under 5 years	- Immunization protocols - Schedules for preventative care visits for children to assess nutrition, growth and development - Workup and treatment for acute respiratory or acute gastrointestinal infections	- Death involving problems of nutrition, dehydration, acute respiratory or acute gastrointestinal infection, not involving HIV.
3.	HIV patients-includes subgroup of infants and children	- Screening schedules, staging criteria and management for HIV - Includes protocols for mothers to prevent transmission to their child	Infant and child – deaths due to complications of HIV infection acquired vertically i.e. failure of prevention of mother to child transmission of HIV.
4.	Maternal health	- Prenatal, peripartum and postpartum care protocols for women	- Deaths of mothers during pregnancy through the 42 day following delivery.
5.	Acute respiratory infections ≥ 5 years of age	- Diagnostic criteria, workup and management	- Deaths from acute respiratory infections, age ≥ 5 years
6.	Acute gastrointestinal infections ≥ 5 years of age	- Diagnostic criteria, workup and management	- Deaths from acute gastrointestinal infections, age ≥ 5 years
7.	Serious adverse drug reactions	- Prevention protocol following first event	- Deaths from adverse drug reactions
8.	Essential hypertension	- Screening, diagnosis, management	- Deaths where the primary cause was hypertension, or with the secondary cause as hypertension where the primary cause was either cerebrovascular accident or myocardial infarction.

Given the relatively small size of Belize, once a patient is registered in the system, full properly spelled name and date of birth are sufficient to link over 98% of cases at a subsequent encounter; rarely, more demographics are needed. Currently, the only new registrations are newborns and foreigners as all citizens are already registered. A very small percentage of patients choose to provide false information at an encounter to try to avoid detection in the country, i.e. illegal immigrants not registered as foreign workers/family or as tourists. For these few, subsequent or previous health information cannot be linked.

1.2. Eight disease prevention/management domains in BHIS

In 2003, the Belize crude mortality rate was 4.66/1000 [7] with a mortality rate of 39/1000 live births for children under

5 years [8]. Hypertension related deaths were the number one cause of death [7]. By 2005, efforts to decrease maternal mortality and mother to child transmission of HIV were gaining modest ground but programmes to decrease hypertension related mortality were having little impact [9]. Based upon these findings, eight domains were selected for clinical decision support algorithms for the BHIS (Table 1). All were supported by evidence based guidelines developed by professional organizations elsewhere but adapted to the Belize context with input and approval by local healthcare professional leaders and community representatives. Many of the guidelines had been recommended in Belize prior to the BHIS but uptake had been limited. Health care workers can override or ignore an algorithm prompt in the BHIS but following is quicker, e.g. appropriate prescription for hypertension with the tick of a box vs. filling in specifics for a different medication.

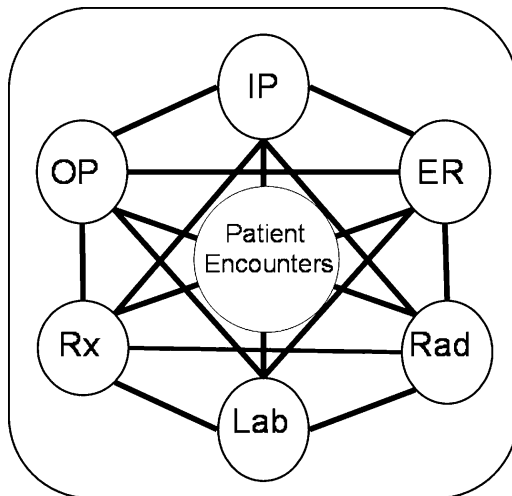


Fig. 3 – Schematic for systems relations in the patient-centred fully integrated health information system in Belize (BHIS). Each encounter area interfaces with every other encounter area linked through the patient. **Legend:** In BHIS: IP = inpatient public and private hospitals; OP = outpatient including public and private clinics, physician and dental offices, military base clinics and public health care delivery sites, i.e. schools, villages, homes, at border entry; Lab = laboratory; Rad = diagnostic imaging; Rx = pharmacy-hospital, clinic or community pharmacy (not include over the counter medications) and ER = emergency services including first responder care.

1.3. Study purpose

The purpose of this study was to assess the impact of the BHIS over its first 4 years by determining: (1) the encounter uptake of the BHIS by health care workers, (2) if pre and post BHIS deployment there were changes in mortality in any of the eight domains with embedded algorithms and (3) if the BHIS was associated with a change in gross government spending on public health care.

2. Methods

From 2007 onwards BHIS encounter data was compared to encounter data captured from standard Ministry of Health reports required from all health care licensed entities that in part determine payments and hence are considered robust data. (Of note, based upon the robustness and quality of the BHIS data, in 2013, the Ministry of Health will shift to only collecting health data using the BHIS.) Mortality data derived from the required registration of all deaths were obtained from the Belize Ministry of Health Epidemiology Unit. The causes of death, primary, secondary and other are assigned by the attending physician as required by law in Belize. This did not change with the BHIS, is independent of the BHIS and the process is consistent with Pan American Health Organization and World Health Organization standards [10,11]. Population estimates for Belize for 2005–2009 were obtained from the Statistical Institute of Belize [12]. The 2010 population data were

obtained from the Belize 2010 Census of Population and Housing [3] and as per Belizean practice the 2011 was estimated. The selected areas for causes of death associated with each of the eight BHIS supported protocols are shown in Table 1.

Three common causes of death in Belize not related to BHIS embedded algorithms; diabetes, diseases of pulmonary circulation, and transport accidents, were selected as comparators. Transport accidents were included as outcomes may be influenced by emergency health care access and quality.

The public expenditures on health for fiscal years 2000–2012 were obtained from the Ministry of Health of Belize.

All analyses were carried out using SAS® (SAS Institute, Cary NC). Ethics review was conducted in accordance with the Belize Ministry of Health Policy. No personally identified data were used in this study. The study was supported by the Government of Belize.

3. Results

Within 1 year of full deployment, i.e. by July 2008, over 90% of all healthcare encounters in Belize in both the public and private sectors, in inpatient and outpatient settings, were being entered into the BHIS, with over 95% by mid-2009 with ongoing slight increases since. Thus the vast majority of health care workers had to be using the BHIS. The very small portion not entered, represents a small number of private system encounters and a tiny fraction of public system encounters scattered across the country in very rural outposts with minimal rudimentary services.

Table 2 presents the crude mortality rates, deaths expressed per 1000 Belizean population, for 2005–2011, for the eight domains with algorithms and the three selected domains without embedded protocols. As the BHIS deployment started midway through 2007, only years 2008 through 2011 had the BHIS available throughout. Three patterns of change in mortality were noted pre and post BHIS deployment.

The first pattern (Fig. 4A) involves domains already being dealt with aggressively prior to BHIS deployment. These included maternal mortality, infant mortality, and mother to child transmission of HIV related mortality. Fig. 5 graphically shows the changes in maternal mortality to better illustrate the pattern. Maternal mortality, infant mortality, and mother to child transmission of HIV all had declining rates prior to BHIS deployment with sharper decline following deployment (mortality rates 2005 vs. 2011; all $p < 0.02$). The national crude infant mortality rate dropped from 39/1000 live births in 2003 [7] to 13/1000 in 2010 [13]. Much of the decrease occurred in disease domains in the BHIS neonatal and infant protocols. Similarly, deaths attributable to mother to child transmission of HIV plummeted within 6 months of BHIS deployment as over 98% of pregnant women received some prenatal care including HIV testing and appropriate HIV management to prevent mother to child transmission of HIV.

The second pattern (Fig. 4B) are areas that showed little change before BHIS deployment but fell steadily thereafter, e.g. mortality rates for children over one but under 5 years, for acute respiratory or acute gastrointestinal infections in those over 5 years, for hypertension and for acute drug reactions. Deaths due to adverse drug reactions dropped by nearly

Table 2 – Crude Mortality for Belize from 2005 to 2010 for eight causes of death with BHIS disease prevention and management protocols embedded, and three casues without BHIS protocols; all expressed as deaths per 1000 population.

Year	Eight areas with BHIS prevention/management protocols								Three areas no BHIS protocols			
	HTN	Mat	Infant	Child	Child HIV deaths MTCH ^a	ADR	ARI ^a	AGI ^a	Total	Diabetes	Diseases of pulmonary circulation	Transport accidents
2005	0.547	0.034	0.209	0.034	0.021	0.120	0.223	0.330	1.518	0.322	0.188	0.267
2006	0.503	0.010	0.139	0.043	0.013	0.126	0.209	0.302	1.346	0.435	0.262	0.226
2007	0.393	0.019	0.058	0.016	0.010	0.093	0.180	0.285	1.054	0.343	0.286	0.205
2008	0.310	0.009	0.031	0.016	0.000	0.009	0.146	0.210	0.731	0.320	0.245	0.220
2009	0.273	0.012	0.030	0.009	0.009	0.006	0.120	0.138	0.597	0.390	0.213	0.156
2010	0.235	0.013	0.025	0.006	0.000	0.006	0.092	0.129	0.507	0.527	0.270	0.311
2011	0.189	0	0.033	0.009	0.006	0.009	0.103	0.108	0.457	0.605	0.298	0.339
<i>p</i> ^{**}	<0.0001	0.006	0.017	0.015	0.010	0.008	0.0002	0.0003	0.457	0.048	NS	NS

HTN, hypertension related mortality; Mat, maternal related mortality; Infant, infant related mortality; Child, child one to under 5 years mortality; Child HIV Deaths, mother to child HIV mortality attributable to mother to child transmission of HIV (MTCH); ADR, adverse drug reaction.

^a Deaths not double counted with child and infant deaths – see Section 2.

^{**} *p* for slope of the line 2005–2011 null hypothesis is slope of the line is zero; two tailed test.

90% within months of deployment as the BHIS required two to three health professionals (physician, pharmacist and/or nurse) to each override the adverse drug system warning and justify this before the patient can receive that drug again. Deaths related to hypertension alone, cerebral vascular accident with hypertension, and myocardial infarction with hypertension all showed significant decreases in mortality ($p < 0.0001$). Physician adherence to prescribing hypertension guideline recommended medications in the BHIS protocol increased to over 94% by 2009. Of note, deaths recorded as myocardial infarction or stroke unrelated to hypertension did not increase after BHIS deployment suggesting that decline in hypertension related deaths was not due to a coding change or omission.

The third pattern (Fig. 4C) are areas where mortality rates did not change consistently over the time period, e.g. diabetes, diseases of pulmonary circulation and transport accidents. None had BHIS embedded clinical decision support algorithms. Compared to diabetes, the changes in hypertension mortality pre and post BHIS deployment differed significantly ($p < 0.0001$ by linear regression). According to the Epidemiology Unit, Belize Ministry of Health, adult hypertension deaths dropped remarkably from being the most common cause of death in Belize in 2003 to ninth in 2011 [4,13], while diabetes lead the mortality list from 2006 onwards [13].

When the 2005 combined mortality rates for these eight domains with BHIS protocols were compared to the combined rate in 2011, a summed mortality decrease of 1.058 per 1000 was noted. In contrast, for the three domains without protocols, there was a summed increase of 0.465 per 1000 (2005 compared to 2011) over the time period. Between 2005 and 2010, the country wide crude death rate for Belize declined from 6.04/1000 to 5.00/1000 population [4,13] in keeping with the declines noted in the eight domains.

The changes in government expenditures on health care (public system) for fiscal years 2000–2012 are shown in Fig. 6. Note expenditures rose steadily until 2009, then declined slightly for the next three fiscal years. While a full cost analysis was not done, pharmaceutical and medical supplies costs did decline following deployment (e.g. 2009–2010 costs vs. 2007–2008 costs pre deployment (\$9,800,000BZD vs. \$10,088,000BZD; 2.8% decrease). Hospital days related to hypertension illnesses declined by over 60% between 2006–2007 and 2010–2011, providing savings of about 1% of the public health care budget.

From 2007 to 2011, there were no major changes in the number or types of health care providers; no sharp increase in continuing education programmes for health care providers although these became more tailored to address care gaps determined by examination of BHIS data [14] and no new disease prevention/management protocols were implemented.

4. Discussion

Health information systems do not make diagnoses, perform surgery or dispense medicines. Benefit only comes if health care professionals are able to practice better, safer, more

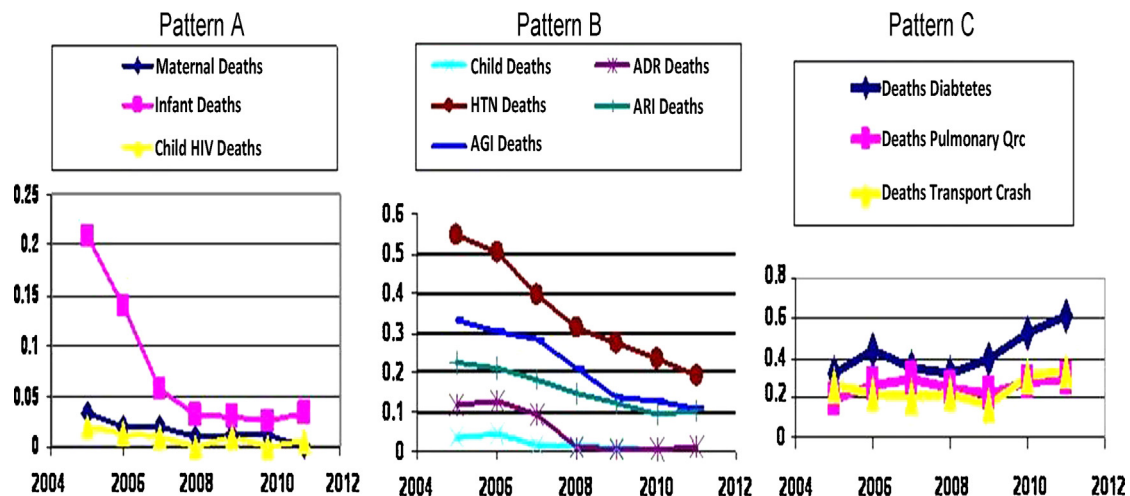


Fig. 4 – Three patterns of change in crude mortality for Belize from 2005 to 2011 for seven causes of death with BHIS embedded protocols and two without; all expressed as deaths per 1000 population. Legend: Maternal = maternal related mortality, Infant = infant related mortality, Child HIV Deaths = mortality attributable to failed prevention mother to child transmission of HIV, <5 = mortality child one to under 5 years, HTN = hypertension related mortality, ARI = acute respiratory infection related mortality in 5 years and older, ADR = adverse drug reaction mortality, Diabetes = diabetes related mortality, Pulm Circ = mortality related to diseases of pulmonary circulation.

effective care using the health information system and many choose to use it. Bearing in mind that Belize is a small middle income developing country, the BHIS was taken up rapidly in all health sectors in all regions of the country. This uptake was temporally associated with decreased mortality in all eight domains with BHIS embedded decision support algorithms but not in three without and with stabilization and then slight declines in annual public health care expenditures.

In contrast to the observations with the BHIS, in developed countries low adoption rates for electronic health information systems by physicians and a litany of barriers to acceptance have been reported [15]. Which of the BHIS development steps, design and/or implementation components supported uptake success across all sectors and regions is still to be determined. A 2011 review of electronic health information systems in Europe suggested that electronic health information system development driven by bureaucrats and software executives is less likely to succeed than

if potential users were much involved [16] as occurred with the BHIS.

Specific BHIS comparators for outcomes and costs are difficult. The two other country wide electronic health information systems are in New Zealand [17] and Denmark [18] but neither has full integration (more in Denmark than in New Zealand), nor the range of embedded clinical decision support algorithms, nor has either reported major declines in mortality following deployment, as seen in Belize with the BHIS. While both cover much larger populations than Belize, the impacts seen with the BHIS have not been reported in sub-regions in either country.

A 2011 systematic review of the literature on impact of electronic health information systems on the quality and safety of health care emphasized the large gap between postulated and empirically demonstrated benefits of these systems [19]. In Belize impact has occurred. The eight embedded decision support algorithms appear to have influenced health practice

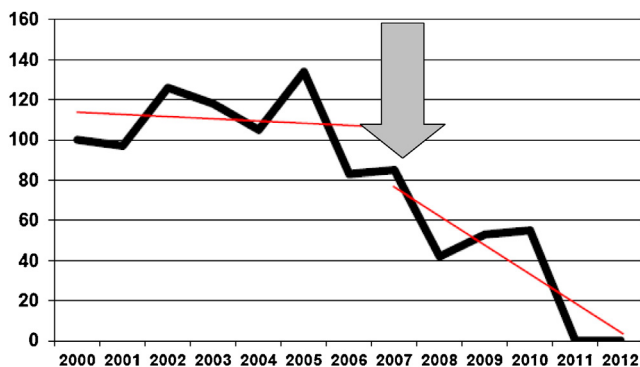


Fig. 5 – Maternal mortality from 2000 to 2012 expressed as rate per 100,000. Live births. Arrow marks BHIS deployment.

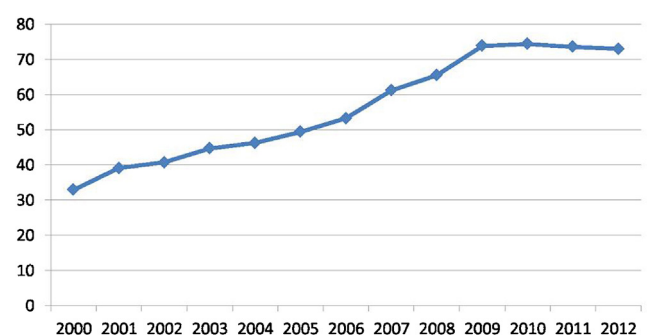


Fig. 6 – Belize annual public healthcare expenditures in millions of Belize dollars (BZD) for fiscal years (April to March) 2000–2012.

Source: Belize Ministry of Health.

country wide as shown by the temporally associated decline in mortality in these eight domains but not in the three domains without. More specifically, with the BHIS with its embedded algorithms, Belize met the Millennium Development Goals 4A and 5A (<http://www.un.org/millenniumgoals/index.shtml>). Both under five mortality (Goal 4A: reduce by two thirds between 1990 and 2015) and maternal mortality (Goal 5A: reduce by three quarters the maternal mortality ratio) were achieved well ahead of the 2015 deadline. Belize met the maternal mortality goal in 2011, becoming the only country in Meso-America likely to do this [14]. As well, to the best of our knowledge, neither country wide nor within country regional dissemination of hypertension guidelines using traditional methods has lead to such rapid changes in practitioner compliance with medication guidelines and sharp decline in hypertension related mortality as seen all across Belize.

Looking at electronic health information technology-enabled programmes in low and middle income developing countries, a 2012 review of 176 such programmes [20], found fragmentation with none having the comprehensive coverage or integration of the BHIS. Only a few had impact data with 6 noting user satisfaction, 5 improvements in care and 4 improved efficiency. No association with a decrease in mortality in a specific area was described.

The development, deployment and ongoing support costs of the BHIS were relatively inexpensive for the health outcomes achieved. In contrast, neither in the United Kingdom nor in Canada, despite large expenditures, has a centralized country wide electronic health information system initiatives been successfully deployed. Both have garnered much criticism for the large amounts spent with meagre or no returns [21–23]. While both countries are many fold larger than Belize and have more complex health care systems, neither has even a regional system functioning at the level of the BHIS. Of note, both countries attempted to connect multiple health information components, a model now falling out of favour with the patient centred architecture used in the BHIS moving to the fore [24]. The 2011 review of electronic health information systems in Europe suggested that regional rather than national foci maybe a better strategy in countries with large populations and complex health care systems [16]. Perhaps, systems with BHIS like patient centred architecture could be developed regionally and then linked at the sub-national and/or national levels.

There are several limitations to this study. This assessment does not prove that the BHIS was causally responsible for the mortality declines in the eight protocol domains; simply demonstrated an association following deployment. However, the only remarkable change in the Belize health programme over this time period was the BHIS with its care algorithms. Gross spending on the public healthcare did not dramatically increase, nor did the standard of living change, nor the numbers of health care providers, nor the access to health care, nor the range of services offered. Health care providers' continuing education sessions did not change in number but the areas targeted did based upon analysis of BHIS programme data. Precisely how the BHIS may have affected practice and in turn health outcomes has yet to be determined but it is noteworthy that practitioner medication prescribing adherence for hypertension management with

the BHIS embedded algorithm rose to over 90%. As well, the Ministry of Health analyzed BHIS maternal care data for evaluation of the management of maternal pre-eclampsia that lead to improved outcomes [14]. The changes in adverse drug reaction mortality rates were dramatic, but whether the earlier rates were excessive is unknown as this area has not been well studied in a developing country. Similarly, whether these observed changes seen with the BHIS were idiosyncratic to Belize or can be generalized await observations from similar systems in other countries. Further research is needed to evaluate the impact of this type of electronic fully integrated patient centred health information programme with embedded algorithms on morbidity, health care practices, resource utilization, health policy decisions and health care costs.

5. Conclusions

The BHIS was built, deployed and is supported to serve the people of Belize; healthcare professionals, administrators, and all citizens in need of health services. For only modest investment, the BHIS has been well used by healthcare providers nationwide, appears to have had an impact on mortality in the eight key BHIS protocol disease domains and been related to stabilization of public healthcare expenditures. Thus the BHIS is more than an electronic medical record or health information system but rather is an electronically facilitated health improvement system with feed forward loops (embedded patient management algorithms) to assist health care providers in making better care decisions and feedback programme review loops to assist health system managers to make better health care system decisions. Whether the same benefits can accrue in other countries or regions of countries are unknown as this type of countrywide electronically facilitated patient centred health care improvement system is new. Regardless, according to the criteria noted by Bohmer [25], the BHIS with its embedded decision support algorithms and processes for utilization of real time data, qualifies the Belize Ministry of Health as a “High-Value Health Care Organization”; an unusual accomplishment for a developing country.

Ethics

Ethics review was conducted in accordance to Belize Ministry of Health Policy. No personally identified data were used in this study.

Funding

As noted in the manuscript, the development of the BHIS was funded as a part of the Belize Health Sector Reform of 2004 Program. No grants or funding were obtained for this analysis.

Author contributions

Dr Michael Graven, is an Assistant Professor of Paediatrics, Dalhousie University and a Senior Advisor to Ministry of Health, Government of Belize. He was the Chief Architect of

the BHIS, involved in its design, development and deployment. He participated in the conception of the BHIS outcome assessment presented in this article, in the study design, data retrieval, analysis, review, and interpretation, table and figure development, and participated in critical discussions on content of the manuscript. He has access to all the data analyzed for this article. He has reviewed and contributed to the final manuscript.

Dr Peter Allen, is the Chief Executive Officer Ministry of Health, Government of Belize, Belmopan, Belize. He was involved in the development and deployment of the BHIS. He participated in the conception of the BHIS outcomes assessment presented in this article, in the design of this study, contributed to the manuscript and has reviewed it.

Mr. Ian Smith is the Director of the BHIS and was involved in deployment and now then maintenance of the BHIS. He participated in the development of the outcome assessment and in data retrieval for this study. He contributed to the manuscript and has reviewed it.

Dr Noni MacDonald is a Professor of Paediatrics, Dalhousie University has been involved in discussions of the BHIS development including protocols since 2006, played a role in the conception of the BHIS outcomes assessment, in the design of this study, in data review and interpretation, in the literature review, wrote the first draft of this manuscript and is responsible for the final content.

Conflict of interests

The authors have no conflicts of interest to declare, but there are competing interests. Both Dr Allen and Mr Smith work for Ministry of Health of the Belizean Government. Drs Graven and MacDonald are employed by Dalhousie University and carry out their clinical practice work at the IWK Health Centre in Halifax, Canada. Dr Graven does not receive any financial remuneration from the Government of Belize in his role as Senior Advisor to the Ministry of Health. With respect to the process engineering firm involved in the BHIS development and deployment, none of the authors have received any honoraria, any payment, own any shares or sit on any advisory boards for the company. There are no known conflicts of interest beyond the relationships to the Ministry of Health of Belize.

Acknowledgements

John Rutter, who passed away in 2008, served as an untiring advocate for the BHIS, and was proud to serve Belize for over 50 years. The success of the BHIS is due, in no small part, to his wisdom and energy.

The BHIS began as a small part of the Belize Health Sector Reform of 2004, under the leadership of the Minister of Health, Right Honourable José Coye; system development continued under the leadership of Minister of Health, Right Honourable Vildo Marin followed by completion of development and then full deployment under the leadership of the current Minister of Health, Right Honourable Pablo Marin.

Summary points

What is already known

- Health information systems do not make diagnoses, perform surgery or dispense medicines.
- Benefit only accrues if health care professionals are able to practice better, safer, more effective care using the health information system and many choose to use it.
- A fully integrated countrywide patient centred health information system with embedded disease management algorithms has never previously been deployed in a developing country and is unusual even in industrialized countries.
- Impact analysis of health information technology in developing countries has rarely been done and seldom has noted impact on health outcomes.

What this study adds

- In Belize, following deployment of a fully integrated countrywide patient centred health information system with embedded disease management algorithms (BHIS), uptake by health care providers all across the country was rapid.
- In the 4 years since BHIS deployment, the mortality rates in the eight domains with embedded algorithms all significantly declined but not in three comparator domains without embedded algorithms.
- With respect to decreases in maternal mortality and under 5 years mortality, Belize met the Millenium Development Goals 4A and 5A in 2011.
- Government expenditures on health care (public system) rose steadily until 2009 and then declined slightly for the next three fiscal years, i.e. post BHIS deployment, in direct contrast to continued escalating health care expenditures in reports from many countries.
- The BHIS has been well accepted, has saved lives, decrease by 1/1000 in crude mortality, and has resulted in less need for expenditure on public health care all for a modest investment (development and deployment \$4 Cad per citizen; yearly maintenance \$3 Cad per citizen).

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