Use of linked data to assess the impact of including out-of-hospital deaths on Canadian national 30-day in-hospital mortality indicators: A retrospective cohort study

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ABSTRACT

Background: The primary objective of this study was to assess the impact of including out-of-hospital deaths on three of CIHI's indicators: *30-Day Acute Myocardial Infarction (AMI) In-Hospital Mortality*, *30-Day Stroke In-Hospital Mortality*, and *Hospital Deaths Following Major Surgery*.

Methods: The study followed national cohorts of patients hospitalized for AMI, stroke, and major surgery for 30-day all-cause mortality in two fiscal years: 2011-12 and 2016-17. Descriptive statistics were calculated to characterize the cohorts. CIHI's Discharge Abstract Database was linked with the Canadian Vital Statistics Death database using a probabilistic algorithm to identify out-of-hospital deaths. Absolute numbers, relative proportions, and 30-day mortality rates were calculated for in-hospital, out-of-hospital, and all deaths. Results were compared between fiscal years.

Results: The number of hospitalizations increased between fiscal years for each indicator; however, cohort characteristics remained stable. In 2016-17, the number of out-of-hospital deaths was 325 for AMI, 545 for stroke, and 820 for major surgery. The relative proportions of out-of-hospital deaths ranged from 12.31% for AMI to 14.86% for major surgery in 2016-17, increasing from 10.56% and 13.06%, respectively in 2011-12. In-hospital mortality rates improved over time for all three indicators, while out-of-hospital mortality rates remained stable between fiscal years at 0.80-0.81% for AMI, 1.92-1.99% for stroke, and 0.24-0.27% for major surgery.

Interpretation: Improvements between fiscal years were attributable to reductions in in-hospital mortality, rather than deaths occurring outside of hospitals. Trends over time were the same for each of the indicators irrespective of whether in-hospital mortality or all deaths were measured.

INTRODUCTION

The Canadian Institute for Health Information (CIHI) supports national data collection, analysis and reporting to accelerate improvements in health system performance across Canada.[1] As part of this work, CIHI annually reports on health system performance indicators, including various 30-day in-hospital mortality rates.[2,3] This information allows for meaningful comparisons about the relative quality and safety of care between different regions,[4-6] supports evidence-based decision-making, and encourages quality improvement initiatives based on approaches applied in high-performing jurisdictions or other countries.[7]

The accuracy of 30-day mortality rates is dependent on the completeness and quality of the available data. CIHI's 30-day mortality rates measure in-hospital deaths documented in administrative health databases such as the Discharge Abstract Database (DAD).[8] This approach has been shown to underestimate overall 30-day mortality rates in other countries, since it does not include deaths that occur outside of the hospital. In order to report more comprehensive measures, administrative health data have been linked with national death registries to capture out-of-hospital deaths.[9] Likewise, in Canada, inclusion of both in-hospital and out-of-hospital deaths may provide a more comprehensive assessment of health system performance. However, this has not yet been examined within the Canadian context.

The primary objective of this study was to assess the impact of including out-of-hospital deaths on CIHI's 30-day in-hospital mortality indicators. This study focused on three of CIHI's annually reported indicators: *30-Day Acute Myocardial Infarction In-Hospital Mortality*, *30-Day Stroke In-Hospital Mortality*, and *Hospital Deaths Following Major*

Surgery. The secondary objective was to assess the performance of the probabilistic linkage algorithm used to identify the additional out-of-hospital deaths.

METHODS

Study design

The pan-Canadian study followed distinct cohorts of acute myocardial infarction (AMI), stroke, and major surgery patients for 30 days after the index hospital date for all-cause mortality. The cohorts were constructed using the same inclusion and exclusion criteria documented in the *denominator description* for each of the respective indicators in CIHI's Indicator Library.[10]

In brief, each cohort includes Canadian residents aged 20 years and older meeting the respective inclusion and exclusion criteria. The AMI and stroke indicators are patient-based, where the index date is the date of hospital admission for only a *first* AMI or stroke within the measurement period. The major surgery indicator is procedure-based and includes all major surgeries performed within the measurement period (i.e., more than one surgery may have been performed on the same patient). The index date for the major surgery indicator is the date of the surgery.

This study reports on the two fiscal years 2011-12 and 2016-17. Cohorts are restricted to acute care hospitalizations with an index date between April 1 and March 1 of the fiscal year to allow for the 30-day follow-up period, and with a discharge from the hospital on or before March 31 in order to be documented in the DAD for the fiscal year.

Data sources

The study was conducted using routinely collected administrative health data from CIHI's DAD linked with data from the Canadian Vital Statistics Death database (CVSD). The databases were linked by Statistics Canada using a probabilistic linkage algorithm based on non-unique identifiers (e.g., name, sex, date of birth, and postal code) and estimates of the likelihood that records could be attributed to the same patient.[11]

The DAD includes administrative, clinical and demographic information on hospital discharges (including in-hospital deaths, sign-outs and transfers) from all provinces and territories, except for Quebec. The CVSD is a census of all deaths occurring in Canada each year. Deaths are reported by the provincial and territorial Vital Statistics Registries to Statistics Canada. The information provided includes demographic characteristics of the deceased and cause of death. Data for the Yukon were not available due to differences in data sharing agreements. Data for Nunavut and the Northwest Territories are not shown due to small numbers.

Measurement of 30-day mortality rates

The outcomes of interest were the absolute numbers of additional deaths identified through linkage with the CVSD, relative proportions of out-of-hospital deaths, and the impacts on the overall 30-day mortality rates of including these deaths. The analyses reported on three types of 30-day mortality metrics:

1) In-hospital deaths: Measured based on acute care hospitalizations documented in the DAD with a discharge disposition code of 07 'discharge as death.' The same inclusion and exclusion criteria were used as documented in the *numerator description* for each of the respective indicators in CIHI's Indicator Library.[10]

2) Out-of-hospital deaths after admission to hospital: Additional deaths identified through the linkage of acute care hospitalizations from the DAD to a death record from the CVSD. Linked records without a documented in-hospital death in the DAD were considered to indicate an out-of-hospital death.

3) All deaths: In-hospital and out-of-hospital deaths.

Statistical analysis

Descriptive statistics were calculated to characterize the sociodemographic information of the AMI, stroke, and major surgery cohorts for fiscal years 2011-12 and 2016-17. Absolute numbers and relative proportions of in-hospital and out-of-hospital deaths were reported. 30-day mortality rates were calculated based on in-hospital, out-of-hospital, and all deaths to quantify the impact of including out-of-hospital deaths in CIHI's indicators. Cumulative mortality was calculated in three-day intervals to assess whether the distributions of in-hospital deaths, occurring either during the index hospital stay or upon readmission, and outside-of-hospital deaths changed over the 30-day follow up. Results were compared between fiscal years.

The performance of the probabilistic linkage algorithm (i.e., coverage rate) was assessed by calculating the percentage of the DAD in-hospital deaths confirmed by linkage to a CVSD death record. The coverage rate was calculated per day over the follow-up period.

All statistical analyses were conducted using SAS 9.4 (SAS Institute Inc., Cary, NC). In order to meet the requirements for publication using CVSD records from Statistics Canada, vetting rules were applied: all counts were rounded to the nearest 5, and rates and proportions were calculated based on the rounded counts.

Ethics Approval

Research ethics board review was not required by the Government of Canada Panel on Research Ethics, because the research involved secondary use of routinely collected clinical administrative health information and was not re-identifiable.

RESULTS

The sociodemographic characteristics of the AMI, stroke, and major surgery cohorts are presented in Table 1. The number of acute care hospitalizations increased from 2011-12 to 2016-17 for each indicator; however, cohort characteristics were stable over time. The absolute numbers and relative proportions of in-hospital and out-of-hospital deaths and associated 30-day mortality rates are reported in Table 2.

30-Day Acute Myocardial Infarction Mortality

In 2016-17, the 30-day AMI in-hospital mortality rate was 5.69% (2,315 deaths/ 40,680 patients). Linkage with the CVSD identified 325 out-of-hospital deaths. Overall, 87.69% of deaths within 30 days were captured in the DAD, and 12.31% occurred outside of the hospital. Including out-of-hospital deaths increased the 30-day mortality rate by 0.80% to 6.49% – representing a 14.06% increase above the in-hospital mortality rate.

Cumulative mortality over the 30-day follow-up period is presented in Figure 1 panels (a) and (b) and showed changes in the distributions of deaths occurring during the index hospital stay, upon readmission, and outside of the hospital over follow up for both fiscal years. Generally, deaths in early follow up occurred during the index hospital stay, with the proportions of deaths upon readmission and outside of the hospital increasing over the follow-up period.

The relative proportion of out-of-hospital deaths increased from 10.56% in 2011-12 to 12.31% in 2016-17 (p=0.04). This change was directly attributable to the decreasing rate of in-hospital mortality over time. The 30-day out-of-hospital mortality rate remained constant at 0.80-0.81% for both fiscal years (Table 2).

30-Day Stroke Mortality

Similar patterns emerged with the 30-day stroke mortality rates (Table 2). In 2016-17, the in-hospital mortality rate was 11.98% (3,275 deaths/ 27,330 patients). An additional 545 deaths were identified through linkage with the CVSD, accounting for 14.27% of all deaths and increasing the overall 30-day mortality rate by 1.99% to 13.98%.

Cumulative proportions of in-hospital versus out-of-hospital deaths over follow up are presented in Figure 1 panels (c) and (d) and showed similar patterns to the AMI indicator. The relative proportion of out-of-hospital deaths increased from 12.05% to 14.27% between fiscal years (p=0.004). Again, the change was a direct result of the decreasing rate of in-hospital mortality. The 30-day out-of-hospital mortality rate remained steady around 1.92-1.99% across both fiscal years (Table 2).

Deaths Following Major Surgery

Notably, all 30-day major surgery mortality rates remained stable over time, with in-hospital mortality rates around 1.54-1.61%, out-of-hospital deaths at 0.24-0.27%, and overall 30-day mortality rates of 1.81-1.85% (Table 2). The relative proportion of out-of-hospital deaths increased from 13.06% in 2011-12 to 14.86% in 2016-17 (p=0.008) due to small variations in relatively low mortality rates. Although the difference was statistically significant due to large sample sizes, it did not represent a clinically important difference in rates. Cumulative percentages of in-hospital versus out-of-hospital deaths

over the follow-up period are presented in Figure 1 panels (e) and (f) and showed similar patterns to the AMI and stroke indicators.

Coverage Rates

The coverage rates (i.e., the percentages of acute care hospitalizations from the DAD with a documented in-hospital death that were matched with a corresponding death record from the CVSD) are reported in Table 3. The overall coverage rates were > 95% for the three indicators across both fiscal years, demonstrating excellent performance by the probabilistic linkage algorithm.

INTERPRETATION

The inclusion of out-of-hospital deaths had differential impacts on the three 30-day mortality indicators. The absolute numbers of deaths, relative proportions of out-of-hospital deaths, and 30-day mortality rates differed between the three indicators, and the indicators followed different trends over time from 2011-12 to 2016-17.

In 2016-17, the number of out-of-hospital deaths was 325 for AMI, 545 for stroke, and 820 for major surgery, which increased the overall unadjusted 30-day mortality rates by 14.06%, 16.61%, and 17.53%, respectively, compared with in-hospital mortality rates. The relative proportion of out-of-hospital deaths ranged from 12.31-14.86% in 2016-17, increasing from 10.56-13.06% in 2011-12.

One constant across all indicators was that 30-day out-of-hospital mortality rates remained stable between the two fiscal years at 0.80-0.81% for AMI, 1.92-1.99% for stroke, and 0.24-0.27% for major surgery. This indicates that observed improvements between fiscal years were mainly attributable to reductions in in-hospital mortality, rather than deaths occurring outside of hospitals. Notably, the trends for each of the indicators

were the same over time irrespective of whether in-hospital mortality or all deaths (i.e., both in- and out-of-hospital) were measured.

The probabilistic linkage algorithm demonstrated excellent performance. Only a small percentage of in-hospital deaths documented in the DAD (range: 3.19% to 4.54%) were not matched to a corresponding death record in the CVSD. These findings suggest that the algorithm also matched > 95% of out-of-hospital deaths with corresponding acute care hospitalizations in the DAD, providing near-perfect coverage of all deaths occurring within the 30-day follow up period.

Similar analyses have been conducted for other countries. The Organisation for Economic Co-operation and Development (OECD) released the *Health at a Glance 2019 – OECD Indicators* report, which compared health system performance across OECD countries.[9] The report provided the following information for 23 member countries about AMI and ischemic stroke: 1) 30-day in-hospital mortality rates for deaths that occurred within the same hospital as the index admission, and 2) overall 30-day mortality rates including deaths that occurred at other hospitals or outside of the hospital. Overall, deaths that occurred in other hospitals or outside of the hospital accounted for 24.2% of 30-day mortality for AMI and 37.4% for ischemic stroke. Notably, the overall 30-day mortality rates reported for Canada did not include out-of-hospital deaths.

Other estimates from government reports and the peer-reviewed literature showed that out-of-hospital deaths (generally defined as deaths occurring after hospital discharge) ranged from 18% to 35% for AMI, and 21% to 43% for stroke.[12-15] The literature did not offer any direct comparisons for the *Hospital Deaths Following Major Surgery* indicator. A related study showed that out-of-hospital deaths following inpatient surgery accounted for 18% of 30-day mortality.[16] Other studies demonstrated how the proportions of out-of-

hospital deaths were dependent on the type of surgery, with out-of-hospital deaths ranging from 8% (bladder) to 50% (breast) after cancer surgeries,[17] and 53% following hip fracture surgeries.[12]

This study reported lower proportions of out-of-hospital deaths compared with the literature at 12.31% for AMI, 14.27% for stroke, and 14.86% for major surgery in 2016-17. A substantial contributor to this variation was the difference in definitions for out-of-hospital deaths between studies. Most studies defined out-of-hospital deaths as those that occurred after discharge from the index hospitalization, which included deaths that occurred during hospital readmissions. This validated CIHI's measurement approach for 30-day in-hospital mortality indicators, which includes deaths that occur during subsequent hospitalizations within 30 days of the index hospital admission date. Figure 1 shows the additional deaths captured by CIHI's indicators when including deaths that occurred upon readmission. The variation could also be explained by: 1) different outcome specifications: for example, the report from New South Wales differentiated between ischemic and hemorrhagic stroke, and reported on 30-day mortality following the last hospital admission in the measurement period;[12] 2) uncertainty around estimates: proportions of out-of-hospital deaths were calculated based on reported point estimates and did not consider the impact of uncertainty of these estimates; 3) older data: despite being published in the last decade, many studies analyzed data from the early to mid-2000s.

This study had several limitations. The reported 30-day mortality rates were not risk adjusted; the study assessed the impact of including out-of-hospital deaths on crude 30-day mortality rates. Although the probabilistic linkage algorithm performed well overall, it is possible that out-of-hospital deaths were undercounted in cases where relevant CVSD records were not matched with corresponding hospitalizations in the DAD.

Future research could evaluate the impact of including out-of-hospital deaths on CIHI's health system performance indicators. This work could also be expanded to assess the impact of out-of-hospital deaths on other indicators, such as CIHI's 30-day readmission rates, where it may be appropriate to censor patients when deaths occur outside of the hospital.

Additional work could focus on improving the probabilistic linkage algorithm to match all documented in-hospital deaths with a corresponding death record in the CVSD. Alternatively, efforts could focus on the implementation of unique patient identifiers to link between CIHI's administrative health databases and the CVSD to facilitate reporting of overall 30-day mortality rates.[9]

In this study, the proportions of out-of-hospital deaths were relatively low and validated CIHI's measurement approach; however, there were significant increases from fiscal year 2011-12 to 2016-17 driven by improvements in in-hospital mortality. It will be important to continue monitoring the proportions of out-of-hospital deaths over time, particularly if substantial improvements are realized for in-hospital mortality and consider modifying the measurement approach given timely access to CVSD records.

Conclusion

CIHI's 30-day in-hospital mortality indicators for AMI, stroke and major surgery provide a reasonable approximation of the overall 30-day mortality rate including out-of-hospital deaths in Canada. The trends over time remained the same whether measuring in-hospital mortality or both in- and out-of-hospital deaths. These findings validate CIHI's measurement approach. Including out-of-hospital deaths would provide a more comprehensive assessment of 30-day mortality; however, the timeliness of CVSD data could negatively impact CIHI's ability to provide timely and actionable information to

accelerate improvements in health system performance.

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Table 1. Sociodemographic Characteristics of the AMI, Stroke, and Major Surgery Cohorts for Fiscal Years 2011-2012 and 2016-2017

	AMI		Stroke		Major surgery	
	2011-2012	**2016-2017**	**2011-2012**	**2016-2017**	**2011-2012**	**2016-2017**
	***n* = 37,255**	***n* = 40,680**	***n* = 23,680**	***n* = 27,330**	***n* = 272,705**	***n* = 304,515**
Age in years, mean ± SD	68 ± 14	68 ± 14	72 ± 14	72 ± 14	62 ± 16	63 ± 16
Female sex, %	12,435 (33.38%)	13,245 (32.56%)	11,640 (49.16%)	12,965 (47.44%)	153,480 (56.28%)	169,360 (55.62%)
Rural or remote residence, %	8,830 (23.70%)	9,395 (23.09%)	4,595 (19.40%)	5,210 (19.06%)	57,025 (20.91%)	62,030 (20.37%)
Province of service,* %						
Newfoundland	1,135 (3.05%)	1,360 (3.34%)	560 (2.36%)	650 (2.38%)	6,275 (2.30%)	6,985 (2.29%)
Prince Edward Island	270 (0.72%)	225 (0.55%)	140 (0.59%)	210 (0.77%)	1,120 (0.41%)	1,250 (0.41%)
Nova Scotia	2,000 (5.37%)	2,180 (5.36%)	955 (4.03%)	1,065 (3.90%)	11,925 (4.37%)	12,825 (4.21%)
New Brunswick	1,585 (4.25%)	1,835 (4.51%)	805 (3.40%)	905 (3.31%)	9,730 (3.57%)	10,805 (3.55%)
Ontario	18,050 (48.45%)	19,725 (48.49%)	11,865 (50.11%)	13,860 (50.71%)	133,840 (49.08%)	150,270 (49.35%)
Manitoba	2,050 (5.50%)	1,995 (4.90%)	1,070 (4.52%)	1,065 (3.90%)	13,430 (4.92%)	13,890 (4.56%)
Saskatchewan	1,600 (4.29%)	1,620 (3.98%)	1,030 (4.35%)	1,110 (4.06%)	11,960 (4.39%)	13,045 (4.28%)
Alberta	4,645 (12.47%)	4,990 (12.27%)	2,835 (11.97%)	3,335 (12.20%)	37,565 (13.77%)	42,885 (14.08%)
British Columbia	5,920 (15.89%)	6,750 (16.59%)	4,420 (18.67%)	5,130 (18.77%)	46,860 (17.18%)	52,560 (17.26%)

Note: AMI = acute myocardial infarction.

* Study excludes data from Quebec and Territories.

Table 2. Absolute numbers and relative proportions of in-hospital and out-of-hospital deaths, and associated 30-day mortality rates for fiscal years 2011-12 and 2016-17

	AMI		Stroke		Major surgery	
	2011-2012	2016-2017	2011-2012	2016-2017	2011-2012	2016-2017
	***n* = 37,255**	***n* = 40,680**	***n* = 23,680**	***n* = 27,330**	***n* = 272,705**	***n* = 304,515**
Absolute number of deaths, No.						
In-hospital deaths	2,540	2,315	3,320	3,275	4,395	4,700
Out-of-hospital deaths	300	325	455	545	660	820
All deaths	2,840	2,640	3,775	3,820	5,055	5,520
Relative proportion, % of *all deaths**						
In-hospital deaths	89.44	87.69	87.95	85.73	86.94	85.14
Out-of-hospital deaths	10.56	12.31*	12.05	14.27*	13.06	14.86*
30-day mortality rate, % of *n*						
In-hospital deaths	6.82	5.69	14.02	11.98	1.61	1.54
Out-of-hospital deaths	0.81	0.80	1.92	1.99	0.24	0.27
All deaths	7.62	6.49	15.94	13.98	1.85	1.81

Note: All deaths include in-hospital and out-of-hospital deaths.

*Statistically significantly different from FY 2011-2012; $p < 0.05$.

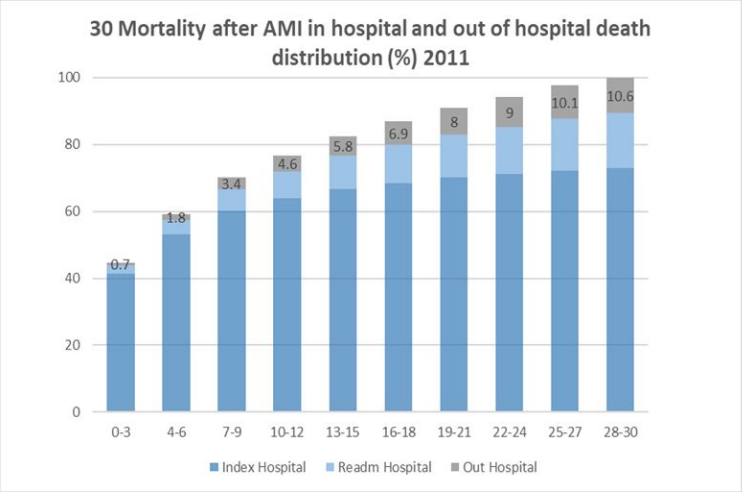
Table 3. Coverage rates: The percentages of acute care hospitalizations from the DAD with a documented in-hospital death that were matched with a CVSD record

	AMI		Stroke		Major surgery	
	2011-2012	**2016-2017**	**2011-2012**	**2016-2017**	**2011-2012**	**2016-2017**
	***n* = 2,540**	***n* = 2,315**	***n* = 3,320**	***n* = 3,275**	***n* = 4,395**	***n* = 4,700**
Absolute number of in-hospital deaths, No.						
Matched to a CVSD death record	2,430	2,210	3,180	3,130	4,220	4,550
Not matched to a CVSD death record	110	105	140	145	175	150
Relative proportion of in-hospital deaths, %						
Matched to a CVSD death record	95.67	95.46	95.78	95.57	96.02	96.81
Not matched to a CVSD death record	4.33	4.54	4.22	4.43	3.98	3.19

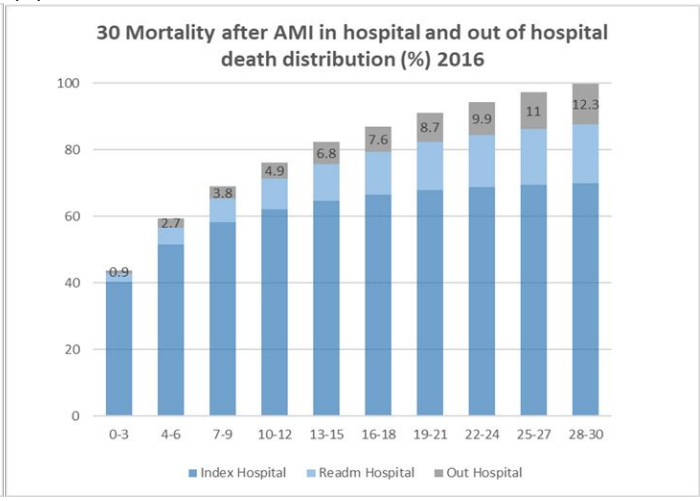
Note: CVSD= Canadian Vital Statistics Death Database, DAD = Discharge Abstract Database.

Figure 1. Proportions of Deaths that Occurred During the Index Hospital Stay, Upon Readmission, and Outside of the Hospital over the 30-day Follow-up Period for each Indicator, by Fiscal Year

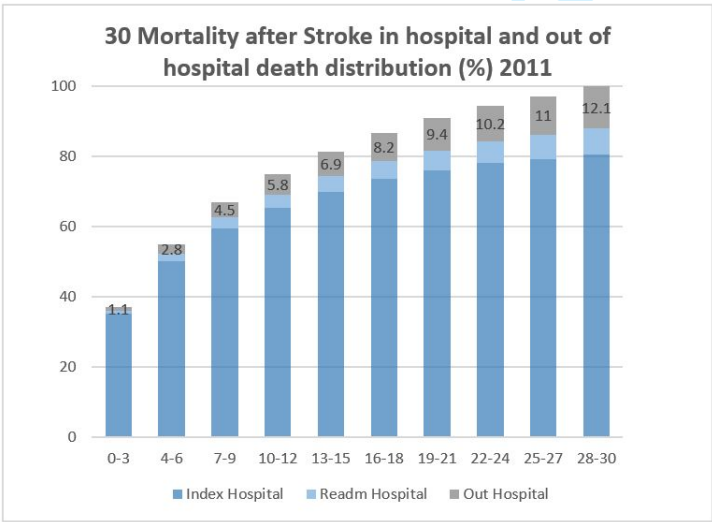
(a) AMI, 2011-12



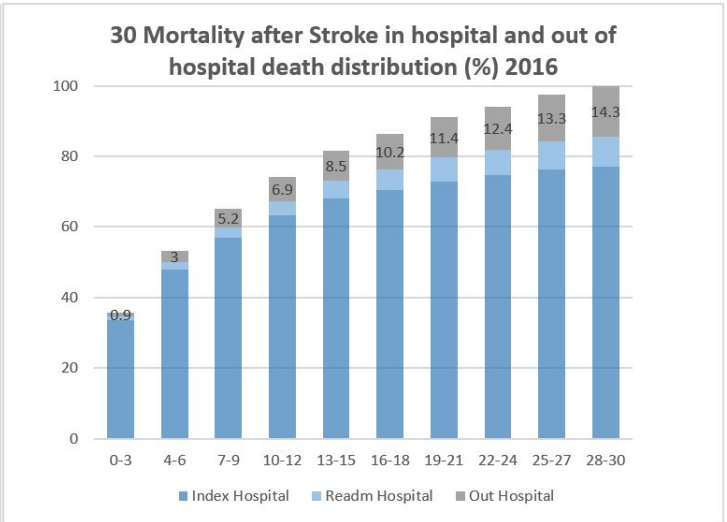
(b) AMI, 2016-17



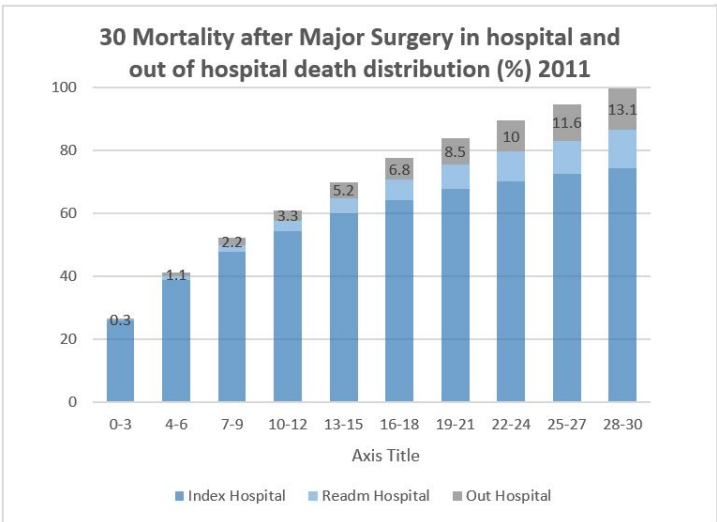
(c) Stroke, 2011-12



(d) Stroke, 2016-17



(e) Major Surgery, 2011-12



(f) Major Surgery, 2016-17