The impact of hospital harm on length of stay, costs of care and length of person-centred episodes of care: a retrospective cohort study

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Cite as: *CMAJ* 2019 August 12;191:E879-85. doi: 10.1503/cmaj.181621

Visual abstract available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.181621/-/DC2

See related article at www.cmaj.ca/lookup/doi/10.1503/cmaj.190912

ABSTRACT

BACKGROUND: There is a lack of data in Canada on the longitudinal effects of adverse events that occur in hospital, specifically in the period after discharge. Our objective was to quantify the impact of adverse events on hospital length of stay, length of person-centred episodes of care (PCEs) and costs of PCEs, as well as their impact on the total health system.

METHODS: We conducted a population-based, retrospective cohort study using linked health administrative databases. We included adults in Ontario who had an acute hospital admission between Apr. 1, 2015, and Mar. 31, 2016. We grouped hospital admissions into 1 of 9 episode types and used the Canadian Institute for Health Information methodology for hospital harm to measure adverse events. We specified generalized linear models to estimate the impact of hospital harm on the following: incremental length of index acute hospital admission, incremental length of the PCE, and incremental costs of the PCE.

RESULTS: Out of 610 979 hospital admissions, 36 004 (5.9%) involved an occurrence of harm. The impact of harm on the incremental length of hospital stay ranged from 0.4 to 24.2 days ($p < 0.001$); the incremental length of the PCE ranged from 0.3 to 30.2 days ($p < 0.001$); and the incremental costs of the PCE ranged from $800 to $51 067 ($p < 0.001$). Total hospital days attributable to hospital harm amounted to 407 696, and the total attributable cost to the Ontario health system amounted to $1 088 330 376.

INTERPRETATION: We found that experiencing harm in hospital significantly affects both in-hospital and post-discharge use of health services and costs of care, and constitutes an enormous expense to Ontario's publicly funded health system.

Patient safety is a key component of high-quality health care delivery as well as an expectation among patients and caregivers. Substantial interest in improving patient safety was prompted following the release of the Institute of Medicine's seminal report, *To Err is Human*,[1] which estimated that between 44 000 and 98 000 Americans died each year as a result of medical mistakes, with an associated cost between US$17 billion and $29 billion. The Canadian Adverse Events Study followed shortly thereafter and estimated that, in 2000, about 185 000 hospital admissions were associated with an adverse event, and close to 70 000 of these were potentially preventable.[2] Despite the substantial attention these findings generated and the policy initiatives they inspired,[3,4] hospital-based adverse events remain a prevalent issue.[5,6] Recently, the Canadian Institute for Health Information (CIHI) partnered with the Canadian Patient Safety Institute to develop a measure of adverse events in hospital — termed "hospital harm" — using administrative health data.[7] This measure is analogous to the Agency for Healthcare Research and Quality's Patient Safety Indicators[8,9] and enables a renewed attention on surveillance of patient safety specific to a Canadian setting.

Although it is understood that experiencing harm in hospital increases length of hospital stay,[5,9,10] costs of hospital care,[9–17] risk of death[9,11,14] and risk of re-admission,[11,14] there is a lack of information on the relation between hospital harm and total cost inclusive of postdischarge use of health services and accompanying costs.[14]

In this study, our objective was to assess the impact of hospital harm on the incremental length of hospital stay, as well as on

the incremental duration and cost of person-centred episodes of care (PCEs), inclusive of acute and postacute care.[18] We additionally sought to assess the total health system impact associated with hospital harm. The PCE methodology creates episodes of care that span acute and postacute care and aligns itself with renewed efforts to draw attention away from sector-specific costs to focus on episodes of care and enable value-based evaluation of health care.[18,19] We hypothesized that hospital harm would lead to significant incremental and total attributable increases in the outcomes of interest.

Methods

Setting and data

We conducted a population-based, retrospective cohort study in Ontario, Canada, using health administrative databases at ICES. These data are inclusive of all hospital, physician, pharmaceutical, laboratory, home care and long-term care paid for by the Ontario Ministry of Health and Long-Term Care. All records were linked sequentially for each study patient by use of encrypted health card numbers. A description of these databases appears in Appendix 1A (Appendix 1, available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.181621/-/DC1). Ontario's health administrative data have been shown to be both valid and reliable,[20] and have been used previously to estimate medical costs[21] and study patterns of health services use.[18,21–25]

Patients

We used PCEs to identify individuals eligible for study inclusion. The complete PCE methodology has been described in detail previously.[18] Briefly, a PCE is defined as beginning with an acute hospital admission and includes subsequent care until an individual has returned to the community and is stabilized for 30 days without any institutional admissions.[18] Person-centred episodes of care are classified according to the clinical grouping for the initial admission and are mutually exclusive. Patients aged 18–105 years on the study index date (Apr. 1, 2015) and eligible for coverage under the Ontario Health Insurance Plan at the time of hospital admission were included. To be eligible for study inclusion, patients had to be discharged alive from an acute hospital admission between Apr. 1, 2015, and Mar. 31, 2016, with a minimum length of stay of 24 hours in one of the following mutually exclusive PCEs of interest: pregnancy, trauma, mental health, cancer, renal, planned surgical, planned medical, unplanned surgical or unplanned medical. Appendix 1B (Appendix 1) contains the full list of exclusions.

Exposure

Our main exposure was the occurrence of a hospital harm in patients' first acute hospital admission in the period between Apr. 1, 2015, and Mar. 31, 2016. We identified hospital harm using the CIHI hospital harm methodology.[7] The CIHI defines hospital harm as a hospital admission in which a patient experiences at least 1 unintended occurrence of harm that is potentially preventable by implementing known evidence-informed safety practices.[7] The methodology consists of 4 major categories of harm that encompass 31 groupings of harmful events. The 4 categories of harm are health care– or medication-associated conditions, health care–associated infections, patient accidents, and procedure-associated conditions.[7] The hospital harm framework employs *International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Canada* codes recorded in the Discharge Abstract Database to identify hospital admissions in which hospital harm occurred. In developing the hospital harm indicator, CIHI ensured a comprehensive data assurance program and included additional steps to determine how useful administrative data were for measuring the occurrence of harm in hospital, including validation of facility-level results by hospitals across Canada.[7,26]

Outcomes

The primary outcomes of this study were the incremental length of acute index hospital stay, duration of the PCE, and costs of the PCE attributable to hospital harm. Length of hospital stay and length of the PCE were measured in days. To measure costs, all records of health care use paid for by the Ontario Ministry of Health and Long-term Care during a PCE were retrieved. The cost associated with each use of health care services was estimated and aggregated over the PCE by use of costing methods developed for health administrative data that have previously been described.[27,28] Costs are reported in 2017 Canadian dollars. We report total attributable acute days, total attributable length of PCEs and total attributable costs of PCEs.

Covariates

We measured several covariates that were hypothesized as confounders in the relation between hospital harm and the outcomes of interest: age, sex, PCE type, neighbourhood income quintile, location of residence, rurality, number of chronic conditions (0, 1, 2, 3, 4, ≥ 5), major clinical category (most responsible diagnosis or intervention that substantially affects the pattern of care and resources consumed by a patient), Hospital Frailty Risk Score[29] (< 5, 5–15, > 15), previous emergency department visits and hospital admissions 1 year before index, hospital type (teaching or community), and postadmission conditions. An interaction term between PCE type and hospital harm was also included. Postadmission conditions are mutually exclusive from the hospital harm indicator and capture conditions reported in previous studies of patient safety.[16] A further discussion of the included covariates appears in Appendix 1C (Appendix 1).

Statistical analysis

We compared baseline characteristics of patients who experienced hospital harm and patients who did not using standardized differences. A standardized difference less than 0.10 was considered negligible.[30] To obtain the best fit to our data, we use regression models and specified generalized linear models with a log link and γ distribution to estimate the incremental effect of hospital harm on length of index hospital stay, duration of PCE, and costs of PCE (following the approach and results of tests recommended by Manning and Mullahy[31] for cost).[32]

Based on this regression, we estimated a prediction of each outcome in patients who did and did not experience hospital

harm, and we used this difference to measure incremental outcomes. The difference between groups (those who experienced hospital harm and those who did not) was assessed via 2-tailed *t* tests. We then calculated the total system impact of hospital harm in terms of total attributable acute days, total attributable PCE days, and total attributable costs per PCE. A *p* value less than 0.05 was taken to indicate differences of hospital harm effects across groups.[33] Further subgroup analyses were conducted by age (< 65 and ≥ 65 yr). Formal testing with interaction *p* values was conducted in considering subgroup differences.

As a sensitivity analysis, we excluded patients with electrolyte and fluid imbalance and also those who developed sepsis after their index admission from the count of patients who experienced a hospital harm, as the status of these as potentially preventable has been contested. We removed the indicator for postadmission conditions from the models as a final sensitivity analysis.

All analyses were performed using SAS Enterprise Guide 7.1.

Ethics approval

The use of data in this project was authorized under section 45 of Ontario's *Personal Health Information Protection Act*, which does not require review by a research ethics board.

Results

We identified a total of 610 979 patients eligible for study inclusion. Characteristics of patients who experienced hospital harm and those who did not appear in Table 1. The largest volume of cases was for unplanned medical PCE (32.3%), whereas renal PCE represented the smallest proportion of cases (0.8%). A breakdown of the cohort by PCE category appears in Appendix 1D (Appendix 1).

Of the 610 979 patients included in the study, 36 004 (5.9%) experienced a hospital harm in their index acute hospital admission. Among patients who experienced a hospital harm, the largest number of patients were admitted for an unplanned medical PCE (24.6%). The incidence of hospital harm within PCEs was highest overall in the trauma PCE (14.1%) and lowest in the mental health PCE (0.6%) (results not shown). Health care– or medication-associated conditions represented the most frequent harm category overall (50.1%).

After adjusting for confounders, we found that the incremental length of hospital stay attributable to hospital harm ranged from 0.4 days (pregnancy PCE) to 24.2 days (mental health PCE). The incremental duration of PCE ranged from 0.3 days (pregnancy PCE) to 30.2 days (trauma PCE). Finally, the incremental costs of PCE ranged from $800 (pregnancy PCE) to $51 067 (unplanned surgical PCE). The incremental length of hospital stay, duration of PCE and costs of PCE were significant in all PCE categories ($p < 0.001$). The full results are shown in Table 2. Results from the multivariable regression analyses appear in Appendices 1E–1G (Appendix 1).

Summing across all PCE categories, the total incremental acute days attributable to hospital harm amounted to 407 696 days; the total incremental PCE days amounted to 661 646 days; and the total incremental costs amounted to $1 088 330 376 (Table 3).

In our first subgroup analysis by age, hospital harm significantly increased length of hospital stay and costs of PCE for both patients younger than 65 years ($p < 0.001$) and patients aged 65 years and older ($p < 0.001$). In patients younger than 65 years, duration of PCE was significantly increased ($p < 0.001$; $p = 0.01$ for unplanned surgical PCE) in all PCEs among those who experienced hospital harm, aside from those in the mental health PCE ($p = 0.6$). Experiencing a hospital harm significantly increased duration of PCE in patients aged 65 years and older ($p < 0.001$).

When we excluded patients with electrolyte and fluid imbalance and those with sepsis (undertaken as separate analyses), the impact of hospital harm on length of stay, duration of PCE and costs of PCE remained consistent and significant. Finally, on removal of the indicator for postadmission conditions, our results also remained consistent and significant. When included as a covariate, the effect of all other postadmission conditions was significant for all outcomes ($p < 0.001$) but much smaller than the effect of hospital harm.

Interpretation

In this population-based study, we measured the attributable length of hospital stay, duration of first PCE, and cost of first PCE in patients who experienced a hospital harm during their acute hospital admission in 1 of 9 PCE catoegories. Of the 610 979 patients included in this study, 36 004 (5.9%) experienced a hospital harm. The attributable length of hospital stay related to experiencing a hospital harm was highest in the mental health PCE, at 24.2 days. The duration of PCE attributable to experiencing a hospital harm was highest in the trauma PCE, at 30.2 days. The incremental cost of PCE attributable to experiencing a hospital harm was highest in the unplanned surgical PCE, at $51 067. Overall, the health system impact of hospital harm amounted to a total of an incremental 407 696 hospital days, 661 646 PCE days and a cost of $1 088 330 376 for the province of Ontario.

Our overall incidence rate of hospital harm of 5.9% is similar to the national incidence rates of 5.6% reported recently by CIHI and 7.5% in 2004 by Baker and colleagues in the Canadian Adverse Events Study.[2,7] Our finding that hospital harm significantly increases length of PCE adds to the literature, as the PCE methodology has only recently been developed.[18] Its use here is timely, as health care systems are increasingly moving toward value-based care that is based on purchasing not only isolated health provider encounters but the outcome produced by all providers centred around a particular health episode. The PCE methodology enables all acute and postacute care, including hospital, physician, pharmacy and home care re-admissions to be captured in the episode of care, an important advance as many of the studies on the costs of adverse events have treated readmissions as initial admissions, leading to bias.[11] More importantly, the use of PCEs highlights that the effects of experiencing harm in hospital extend to the postdischarge period, supporting earlier results from the United States and Denmark.[14,17]

Table 1: Baseline characteristics of 610 979 patients, by hospital harm status

Characteristic	No. (%) of patients*		Standardized difference
	Hospital harm *n* = 36 004	No hospital harm *n* = 574 975	
Age, yr, mean ± SD	64.88 ± 19.83	55.94 ± 21.02	0.44
Sex, female	20 282 (56.3)	350 975 (61.0)	0.10
Neighbourhood income quintile			
Q1 (lowest)	8571 (23.8)	136 070 (23.7)	0.00
Q2	7972 (22.1)	121 293 (21.1)	0.03
Q3	7150 (19.9)	113 086 (19.7)	0.00
Q4	6231 (17.3)	104 643 (18.2)	0.02
Q5 (highest)	6015 (16.7)	98 954 (17.2)	0.01
Rural residence	4034 (11.2)	72 331 (12.6)	0.04
No. of chronic conditions			
0	11 288 (31.4)	129 606 (22.5)	0.20
1	3170 (8.8)	91 936 (16.0)	0.22
2	3441 (9.6)	88 306 (15.4)	0.18
3	3959 (11.0)	79 057 (13.7)	0.08
4	4152 (11.5)	63 977 (11.1)	0.01
≥ 5	9994 (27.8)	122 093 (21.2)	0.15
Major clinical category, intervention†	18 256 (50.7)	224 466 (39.0)	0.24
Hospital Frailty Risk Score[29]			
Low risk (< 5)	29 186(81.1)	564 046 (98.1)	0.58
Intermediate (5–15)/high risk (> 15)‡	6818 (18.9)	10 929 (1.9)	0.58
Teaching hospital	14 844 (41.2)	176 176 (30.6)	0.22
Postadmission conditions, yes	–	47 025 (8.2)	–
PCE category			
Pregnancy	4524 (12.6)	117 361 (20.4)	0.21
Trauma	6175 (17.2)	37 774 (6.6)	0.33
Mental health	229 (0.6)	38 404 (6.7)	0.33
Cancer	4284 (11.9)	34 153 (5.9)	0.21
Renal	425 (1.2)	4314 (0.7)	0.04
Planned surgical	6080 (16.9)	104 131 (18.1)	0.03
Planned medical	183 (0.5)	5359 (0.9)	0.05
Unplanned surgical	5237 (14.5)	45 212 (7.9)	0.21
Unplanned medical	8867 (24.6)	188 267 (32.7)	0.18
Harm category			
Health care– or medication-associated conditions	18 027 (50.1)	–	–
Health care–associated infections	13 328 (37.0)	–	–
Patient accidents	967 (2.7)	–	–
Procedure-associated conditions	9819 (27.3)	–	–
No. of hospital admissions within 1 yr before index admission, mean ± SD	0.30 ± 0.82	0.22 ± 0.70	0.11
No. of ED visits within 1 yr before index admission, mean ± SD	1.30 ± 2.36	1.31 ± 2.99	0.01

Note: ED = emergency department, PCE = person-centred episodes of care, SD = standard deviation.
*Unless stated otherwise.
†*International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Canada* diagnosis codes are used to categorize patients into major clinical categories. These broad categories are based on the most responsible diagnosis code. This diagnosis is the one determined to have been responsible for the greatest portion of the patient's length of stay. Major clinical categories are divided into 2 partitions: intervention and diagnosis.
‡Because of small cell counts in those deemed high risk based on Hospital Frailty Risk Score, intermediate and high-risk groups were combined.

Limitations

The CIHI hospital harm methodology does not capture all harmful events that occur in hospital; only harms identified as potentially preventable are included.[7] A more comprehensive list of the types of harm not captured by the methodology is described elsewhere.[7] It should be stressed that while the methodology aims to identify only potentially preventable instances of harm, not all instances of harm actually are preventable. In a recent review on adverse events in health care, it was reported that between one- and two-thirds of hospital adverse events are estimated to be preventable.[34] Such estimates have implications for the results of this study. If only two-thirds of cases of the hospital

Table 2: Impact of hospital harm on incremental length of hospital stay, incremental duration of first person-centred episode of care and incremental costs of first person-centred episode of care*

	Length of hospital stay, d, mean ± SD				Duration of first PCE, d, mean ± SD				Cost of first PCE, 2017 Can$, mean ± SD			
PCE category	Hospital harm	No hospital harm	Incremental	*p* value	Hospital harm	No hospital harm	Incremental	*p* value	Hospital harm	No hospital harm	Incremental	*p* value
Pregnancy	3.5 ± 0.3	3.1 ± 0.3	0.4 ± 0.3	< 0.001	35.0 ± 1.6	34.6 ± 2.0	0.3 ± 2.0	< 0.001	6172 ± 896	5373 ± 909	800 ± 909	< 0.001
Trauma	25.0 ± 10.2	7.7 ± 2.9	17.3 ± 4.9	< 0.001	82.0 ± 16.3	51.8 ± 11.6	30.2 ± 12.5	< 0.001	70556 ± 28063	22732 ± 8496	47824 ± 13732	< 0.001
Mental health	34.3 ± 12.8	10.1 ± 4.0	24.2 ± 4.6	< 0.001	85.2 ± 23.7	58.0 ± 43.4	27.2 ± 42.9	< 0.001	43693 ± 16913	25679 ± 17502	18014 ± 17481	< 0.001
Cancer	18.0 ± 5.7	6.5 ± 1.1	11.5 ± 2.3	< 0.001	62.9 ± 8.5	46.2 ± 4.5	16.7 ± 5.2	< 0.001	48775 ± 15086	21424 ± 4686	27351 ± 6879	< 0.001
Renal	19.6 ± 7.9	8.2 ± 3.0	11.4 ± 3.8	< 0.001	68.2 ± 12.6	52.7 ± 16.8	15.6 ± 16.4	< 0.001	49732 ± 18458	23421 ± 8406	26311 ± 9913	< 0.001
Planned surgical	10.6 ± 3.0	3.7 ± 0.5	6.9 ± 0.9	< 0.001	51.0 ± 6.5	37.3 ± 3.7	13.6 ± 3.9	< 0.001	35406 ± 11033	12375 ± 2551	23031 ± 3699	< 0.001
Planned medical	22.2 ± 7.7	6.7 ± 1.4	15.5 ± 2.0	< 0.001	75.8 ± 11.7	49.5 ± 11.6	26.3 ± 11.6	< 0.001	51719 ± 16264	18362 ± 5807	33357 ± 6495	< 0.001
Unplanned surgical	22.4 ± 8.9	6.6 ± 1.4	15.8 ± 3.3	< 0.001	71.3 ± 13.2	46.2 ± 313.5	25.1 ± 294.1	< 0.001	70232 ± 28108	19164 ± 23636	51067 ± 24216	< 0.001
Unplanned medical	19.4 ± 8.2	6.7 ± 1.8	12.7 ± 2.5	< 0.001	67.1 ± 17.5	47.9 ± 88.4	19.1 ± 86.3	< 0.001	44353 ± 19146	16909 ± 11945	27445 ± 12396	< 0.001

Note: PCE = person-centred episodes of care, SD = standard deviation.
*Incremental outcomes and *p* values are adjusted by all the covariates of interest (Appendix 1, available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.181621/-/DC1).

Table 3: System impact during episodes of care associated with hospital harm during fiscal year 2015/16*

		Incremental acute days		Incremental duration of first PCE		Incremental cost of first PCE, 2017 Can$	
PCE category	No. of cases of harm	Days per patient	Total days	Days per patient	Total days	Cost per patient	Total cost
Pregnancy	4524	0.38	1700	0.32	1468	800	3 617 540
Trauma	6175	17.27	106 645	30.21	186 553	47 824	295 313 077
Mental health	229	24.23	5549	27.23	6235	18 014	4 125 135
Cancer	4284	11.50	49 247	16.72	71 618	27 351	117 169 842
Renal	425	11.39	4842	15.57	6619	26 311	11 182 128
Planned surgical	6080	6.89	41 875	13.64	82 941	23 031	140 027 325
Planned medical	183	15.55	2845	26.29	4811	33 357	6 104 265
Unplanned surgical	5237	15.80	82 750	25.14	131 679	51 067	267 439 974
Unplanned medical	8867	12.66	112 244	19.14	169 722	27 445	243 351 091
Total	36 004	11.32	407 696	18.38	661 646	30 228	1 088 330 376

Note: PCE = person-centred episodes of care.
*Incremental outcomes are adjusted by all the covariates of interest.

harms measured in this study were preventable, the overall health system impact would be reduced to a total of 271 798 hospital days, 441 097 PCE days and $725 553 584. This highlights that caution must be taken in interpreting these results and drawing conclusions about which events can feasibly be the targets of patient safety initiatives, as the method of defining hospital harm and attributing costs is designed to be inclusive, potentially leading to an overestimate. However, the CIHI hospital harm methodology aims to focus on potentially preventable events and excludes many postadmission hospital events (captured in our measure of other postadmission events). We undertook additional sensitivity analyses by excluding patients with electrolyte and fluid imbalance and those who developed sepsis after their index admission. Our results remained consistent and significant following both of these exclusions. Finally, there is a possibility that there may be unmeasured confounders, such as body mass index. This information is currently unavailable in administrative databases.

Conclusion

We found that experiencing hospital harm significantly increases length of hospital stay, length of PCE and costs of PCE. We employed the CIHI hospital harm methodology at a provincial level, which enabled us to estimate the total health system impact of hospital harm in Ontario. Financially, this amounted to $1 088 330 376 in 2017 Canadian dollars and 407 696 acute hospital days or the equivalent of a 1117-bed hospital operating at 100% capacity between Apr. 1, 2015, and Mar. 31, 2016. Substantial investments in strategies to reduce adverse events could result in cost savings and additional benefits to patients. Future research should assess the impact of preventable harm on other outcomes, such as patient-reported outcomes, patient-reported experiences, re-admissions and death.

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Competing interests: None declared.

This article has been peer reviewed.

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Contributors: All authors contributed to the study design (exposure and outcome measure conceptualization). Sara Guilcher, Yu Qing Bai and Walter Wodchis contributed to the data acquisition. Yu Qing Bai performed the data analysis. All of the authors contributed to the data interpretation. Lauren Tessier drafted the manuscript, which all authors revised. All of the authors approved the final version to be published and agreed to be accountable for all aspects of the work.

Funding: This research was supported by a grant from the Ontario Ministry of Health and Long-Term Care (MOHLTC) to the Health System Performance Research Network (fund #06034, recipient W.P.W.), and by ICES, which is also funded by an annual grant from the Ontario MOHLTC. The opinions, results and conclusions reported in this paper are those of the authors and are independent from funding sources. No endorsement by ICES or the Ontario MOHLTC is intended or should be inferred. Parts of this material are based on data and information compiled and provided by the Canadian Institute for Health Information (CIHI). However, the analyses, conclusions, opinions and statements expressed herein are those of the authors, and not necessarily those of CIHI. The authors thank CIHI for use of their hospital harm indicator. Sara Guilcher is supported by the Canadian Institutes for Health Research Embedded Clinician Scientist Salary Award in Transitions in Care.

Data sharing: The data from this study are held securely in coded form at ICES. Although data-sharing agreements prohibit ICES from making the data publicly available, access may be granted to those who meet prespecified criteria for confidential access (available at www.ices.on.ca/DAS).

Accepted: June 13, 2019

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