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Barriers and facilitators to adopting high value practices and de-adopting low value practices in the Intensive Care Unit: A multi method study

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ABSTRACT

Objective: To compare and contrast illustrative examples of the adoption of high value practices and the de-adoption of low value practices.

Design: 1) Retrospective, population-based audit of low molecular weight heparin (LMWH) for venous thromboembolism (VTE) prophylaxis (high value practice) and albumin for fluid resuscitation (low value practice) and 2) Cross-sectional survey of healthcare providers.

Setting: Data were collected from nine adult medical-surgical ICUs in two large Canadian cities. Patients are managed in these ICUs by a group of multi-professional and multi-disciplinary healthcare providers.

Participants: Participants included 6946 ICU admissions and 309 healthcare providers from the same ICUs.

Main Outcome Measures: 1) The use of LMWH for VTE prophylaxis (percent ICU days) and albumin for fluid resuscitation (percent of patients); and 2) provider knowledge of evidence underpinning these practices, and barriers and facilitators to adopt and de-adopt these practices.

Results: LMWH was administered on 38.7% of ICU days, and 20.0% of patients received albumin.

Most participants had knowledge of evidence underpinning VTE prophylaxis and fluid resuscitation (59.1% and 84.2%, respectively). Providers perceived these practices to be followed. The most commonly reported barrier to adoption was insufficient knowledge/understanding (32.8%), and to de-adoption was clinical leader preferences (33.2%). On-site education was the most commonly identified facilitator for adoption and de-adoption (67.8% and 68.6%, respectively).

Conclusions: Despite knowledge of and self-reported adherence to best practices, the audit demonstrated opportunity to improve. Provider-reported barriers and facilitators to adoption and de-adoption are broadly similar.

KEY WORDS: Intensive Care; Appropriateness, Under-use and Over-use; Healthcare System; Quality Improvement

STRENGTHS & LIMITATIONS

- A strength of this study is the use of mixed-methods to comprehensively compare adoption of high value practices and de-adoption of low value practices in the ICU.
- Another strength is the use of population-based data to capture current clinical practices.
- A limitation of this study is related to the survey used to assess barriers and facilitators of the two illustrative practices; perfection was compromised to optimize the practicality of the survey.

- Another limitation is the comparison of two practices, which may account for some of the differences observed between adoption of the high value practice and de-adoption of the low value practice.
- Our study provides several insights into similarities and differences between adoption of high value practices and de-adoption of low value practices.

INTRODUCTION

Optimizing the quality of care[1] is of particular importance in the intensive care unit (ICU) due to the acuity of patient illness and substantial resources required to care for these patients. However, it is estimated that practice change (adopting high value practices or de-adopting low value practices) can take up to 17 years.[2] To minimize the latency for change, it is important find ways to improve the implementation of evidence-based practices.

A growing body of evidence has evaluated barriers and facilitators for adopting high value practices (effective at improving outcomes).[3-6] Substantially less is known about the barriers and facilitators for de-adopting low value practices (ineffective at improving outcomes or harmful), and how they compare to those for adopting high value practices.[7,8] De-adoption is the discontinuation of a practice that has been previously adopted.[9] Terminology used to describe de-adoption is voluminous – over 43 terms have been identified, with little consensus on the most appropriate term.[7] Some have suggested that the adoption of high value practices and de-adoption of low value practices involve similar processes and common facilitators and barriers;[10,11] however, others suggest that the two are clearly distinct.[8,12] There has been limited comparative evaluation of adoption and de-adoption and this is an important knowledge gap given the growing number of initiatives aimed at de-adopting low value practices.[13-16]

The two illustrative practices (one for adoption of a high value practice and one for de-adoption of a low value practice) used in our study were chosen by a network of medical-surgical ICUs based on published evidence and stakeholder engagement.[17] The expanding evidence (randomized trials, a systematic review and meta-analysis, and an economic evaluation)[18-20] suggests LMWH is a high value practice relative to unfractionated heparin (UFH) for VTE prophylaxis, which is also reflected in recent international and local clinical practice guidelines.[21,22] The evidence (multiple randomized trials and a systematic review)[23] indicates that albumin is a low value practice relative to crystalloids for fluid resuscitation. Patient and family representatives, frontline providers and decision-makers considered the totality of the evidence from a clinically grounded perspective (i.e., evaluated the evidence using a patient-centred and healthcare focused perspective), and through validated consensus methods chose low molecular weight heparin (LMWH) for venous thromboembolism (VTE) prophylaxis and albumin for fluid resuscitation as illustrative examples of adoption of a high value practice and de-adoption of a low value practice, respectively.[17]

METHODS

Aim

The objective of this study was to describe illustrative example practices of the adoption of high value practices and the de-adoption of low value practices in the ICU. The results of this study prompted a subsequent implementation study to improve these two practices. The audit data identified important opportunities to improve

clinical care, and the perceived barriers and facilitators identified in the survey were used to inform the development of interventions.

Study design

This multi-method observational study included: 1) a retrospective cohort study of patients admitted to ICUs to describe current VTE prophylaxis and fluid resuscitation practices, and 2) a cross-sectional survey of ICU healthcare providers to examine: knowledge of evidence underpinning these two practices, and perceived barriers and facilitators to adopt LMWH for VTE prophylaxis and de-adopt albumin for fluid resuscitation.

Setting

All data were collected from nine adult medical-surgical ICUs in the two largest cities in a Canadian province (population of 4.1 million). A single health services provider is responsible for the provision of all hospital-based care in the province and uses a single formulary across all ICUs (clinical practices may differ between cities and sites). ICU patients are managed by a multi-disciplinary and multi-professional group of healthcare providers, including (but not limited to): physicians, medical trainees (clinical fellows and residents), nurse practitioners (NPs with prescribing privileges), pharmacists, and nurses (managers, educators, bedside).

Audit of current practices

Participants

We included patients admitted to nine adult medical-surgical ICUs between January 1, 2014 and December 31, 2014. For analyses, patients were grouped into two cohorts.

1) The adoption cohort consisted of patients without a contraindication for pharmacological VTE prophylaxis where according to international and local guidelines LMWH should be prescribed.[18,21,22,24,25] Contraindications to pharmacological prophylaxis included a diagnosis potentially associated with a high risk of bleeding (Supplemental Content 1), daily assessed platelet count <50 $x10^9$/L, INR ≥2, PTT ≥55 seconds, or receipt of therapeutic anti-coagulation.

2) The de-adoption cohort consisted of patients without an indication for use of albumin for fluid resuscitation and where according to the current evidence-base albumin should not be used for fluid resuscitation.[23,26-28] Potential indications for albumin included documented liver disease (cirrhosis or hepatic failure), or receipt of plasma exchange.[29-32] The two study cohorts were drawn from the same patient population and patients satisfying both sets of clinical indications were included in both cohorts.

Data source

All nine ICUs employ a shared integrated, prospective, clinical information system that captures and delivers multimodal patient data (demographic, clinical, outcome) in real time to the bedside (eCritical MetaVision, iMDsoft, MetaVision), and is also a repository and clinical analytics system that stores these data (eCritical TRACER) to support quality improvement and clinical research. eCritical TRACER was used to extract all data.

Variables

Patient and ICU demographic variables included age, sex, comorbidities, admission type, disease severity (APACHE II score), ICU and hospital length of stay, ICU and hospital mortality. Data abstracted included: 1) type of VTE prophylaxis (mechanical included antiembolic stockings and sequential compression devices, and pharmacological included UFH and LMWH), 2) ICU day that VTE prophylaxis was administered, 3) if the patient received albumin, 4) quantity (units) of albumin, and 5) ICU day that albumin was administered. An ICU day was defined as any portion of a day between 07:00 and 06:59, recognizing that follow-up time on admission day and discharge day may be less than 24 hours.

Data analysis

Descriptive statistics (means with standard deviations [SD], medians with interquartile ranges [IQR], frequencies with proportions) were used to describe the two cohorts. The proportion of admissions and ICU days with LMWH, UFH, and mechanical VTE prophylaxis by ICU and ICU day; and with any albumin administration by ICU and patient were calculated to describe current clinical practices.

To examine potential associations between demographic and site-level factors, and the adoption of the high value practice (LMWH) a multivariable generalized estimating equations (GEEs) logistic regression model with exchangeable correlation structure given daily measurements (clustering by patient) was used. To examine potential

associations between demographic and site-level factors, and the de-adoption of the low value practice (albumin) a multivariable logistic regression model given a single measurement per patient was used.

Barriers and facilitators to adopting LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation

Survey development

The survey was modeled after previous work on adoption of LMWH for VTE prophylaxis,[33] and refined to include questions regarding fluid resuscitation. Because research around barriers and facilitators of de-adopting low value practices is in its infancy[34] the evidence of barriers and facilitators for adopting high value practices was employed.

The survey was divided into four sections: participant demographic information, knowledge of the current evidence underpinning the best practices, and perceptions of barriers and facilitators to the use of the two illustrative examples of best practices (Supplemental Content 2).

The survey was pilot tested in two phases: Phase 1) Seven providers completed the survey and identified unnecessary, missing, or poorly worded items. The survey was modified and pilot tested with 12 additional ICU providers (1 attending physician, 2 residents, 1 clinical fellow, 1 nurse practitioner, 1 nurse manager/charge nurse, 1 nurse educator, 2 bedside nurses, and 3 pharmacists). Phase 2) Providers completed

the survey twice (7-10 days apart) and an additional brief questionnaire to rate the clinical sensibility of the survey. Test-retest reliability of the survey demonstrated a mean intraclass correlation coefficient (ICC) of 0.66 (SD 0.47) for continuous responses and a mean proportion of agreement of 0.86 (SD 0.10) for categorical responses. The low ICC for continuous responses is due to low variability in responses for questions relating to knowledge of best practices. The participants agreed that the survey had face validity (100%), content validity (92%), clarity (92%), utility (100%), discriminability (75%), and minimal redundancy (100%).

Participants

Healthcare providers (as described in Setting) that cared for patients in the nine ICUs were invited by email to participate in the study. Invitations to participate were sent to healthcare providers by the principal investigators or by a local clinical leader and included a link to the electronic survey (Fluid Survey) or were provided a paper copy if requested. Weekly reminders were sent for three weeks. Providers that responded to the survey were offered entry into a draw for one of three $20 coffee gift cards.

Data Analysis

We used descriptive statistics to describe demographic features of participants, knowledge of best practices, perceived barriers to adopting high value practices and de-adopting low value practices, perceived facilitators to encourage adopting high value practices and de-adopting low value practices. Barriers and facilitators to the use of best practices were described overall, and by professional group. Professions

were categorized into three groups for analysis: 1) Physicians/NPs (those who prescribe), 2) Nurses (those who administer), and 3) Pharmacists (those who advise prescribers). Chi-squared tests were used to test for statistical significance between groups.

Ethical considerations

This study was approved by the University of Calgary Conjoint Health Research Ethics Board (REB14-0992 and REB15-2147) and the University of Alberta Research Ethics Board (Pro00056709 and Pro00060650).

RESULTS

Audit of current practices

Patients

There were 6,946 ICU admissions during the study period, from 6,299 unique patients. The typical ICU admission was a 60 (IQR=46-71) year old male (58.4%), with at least one comorbidity (44.6%), and admitted for a medical reason (59.9%). The median ICU and hospital length of stay were 3.7 (IQR=1.8-7.7) days, and 13.3 (IQR=6.1-29.5) days, respectively. ICU and hospital mortality were 14.1% and 21.0%, respectively (Supplemental Content 3).

The adoption cohort consisted of 4,931 admissions (71.0% of all admissions) without a contraindication to pharmacological VTE prophylaxis, and the de-adoption cohort

consisted of 6,467 admissions (93.1%) without a potential indication for albumin (Figure 1).

VTE prophylaxis (adoption cohort)

During the ICU stay LMWH was given on 38.7% of ICU days, UFH on 45.3% of ICU days and mechanical prophylaxis (exclusive of pharmacological prophylaxis) on 7.7% of ICU days. The type of VTE prophylaxis administered varied throughout patients' ICU stay; administration of mechanical devices and UFH decreased over the course of the ICU stay while administration of LMWH increased (Figure 2).

Albumin for fluid resuscitation (de-adoption cohort)

6,804 units of albumin were administered to 20.0% of the 6,467 admissions without documented liver disease or receipt of plasma exchange. Among those receiving at least 1 unit of albumin, the median number of units per patient was 3 (IQR=1.0-6.0). Albumin was administered on 6.5% of ICU days.

When controlling for demographic and site-level factors, there were no differences in adoption or de-adoption based on patient age, sex, or comorbidity (Supplemental Content 4). The odds of adopting LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation were significantly lower for those patients with higher severity of illness (APACHE II score). The odds of adopting LMWH for VTE prophylaxis were significantly higher for patients with non-surgical admissions compared to those with elective surgical admissions (odds ratio = 1.34 (95%

confidence interval 1.08-1.66); Supplemental Content 4). There were significant differences in the odds of adopting LMWH for VTE prophylaxis, and de-adopting albumin for fluid resuscitation across ICUs (Supplemental Content 4 and 5).

Barriers and facilitators to adopting LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation

Participants

83.8% (259 of 309) of participants responded; physicians/NPs (48.3%), nurses (42.5%), and pharmacists (9.3%). Participants worked in healthcare for a median of 13 years (IQR=7.1-20.0) and in critical care for a median of 8 years (IQR=3.0-15.0; Supplemental Content 6).

Knowledge of evidence

Most participants reported that LMWH was most effective at preventing deep vein thrombosis and pulmonary embolism; and that crystalloids were most effective for fluid resuscitation (Table 1). Perceptions regarding the effectiveness of VTE prophylaxis varied by professional group, as did perceptions regarding the risks of harm (Table 1). Perceptions regarding effectiveness of albumin for fluid resuscitation and risks of harm associated with each form of fluid resuscitation did not vary by professional group but perceptions regarding the risk of fluid overload did (Table 1).

It was perceived that both best practices were being followed in the ICUs where the participants practiced (Table 1).

Table 1. Knowledge of best practices for VTE prophylaxis and fluid resuscitation

	% (N)			
Survey question	**Overall N=259**	**Physicians/NPs 48.3% (N= 125)**	**Nurses 42.5% (N= 110)**	**Pharmacists 9.3% (N= 24)**
What form(s) of prophylaxis is/are most effective at preventing deep vein thrombosis?*				
LMWH only	59.1 (153)	63.2 (79)	51.8 (57)	70.8 (17)
UFH only	4.3 (11)	2.4 (3)	7.3 (8)	0.0 (0)
LMWH & UFH	16.2 (42)	24.0 (30)	5.5 (6)	25.0 (6)
Mechanical only	1.9 (5)	0.0 (0)	4.6 (5)	0.0 (0)
(LMWH or UFH) and Mechanical	15.1 (39)	8.0 (10)	25.5 (28)	4.2 (1)
Unsure only	3.5 (9)	2.4 (3)	5.5 (6)	0.0 (0)
What form(s) of prophylaxis is/are most effective at preventing pulmonary embolism? *				
LMWH only	56.8 (147)	72.0 (90)	33.6 (37)	83.3 (20)
UFH only	18.2 (47)	1.6 (2)	40.9 (45)	0.0 (0)
LMWH & UFH	12.7 (33)	20.8 (26)	3.6 (4)	12.5 (3)
Mechanical only	0.4 (1)	0.0 (0)	0.9 (1)	0.0 (0)
(LMWH or UFH) & Mechanical	8.5 (22)	3.2 (4)	15.5 (17)	4.2 (1)
Unsure only	3.5 (9)	2.4 (3)	5.5 (6)	0.0 (0)
Which form(s) of prophylaxis is/are most cost effective?*				
LMWH only	51.0 (132)	70.4 (88)	22.7 (25)	79.2 (19)
UFH only	15.4 (40)	12.8 (16)	20.0 (22)	8.3 (2)
LMWH & UFH	4.3 (11)	5.6 (7)	0.9 (1)	12.5 (3)
Mechanical only	10.0 (26)	4.8 (6)	18.2 (20)	0.0 (0)
(LMWH or UFH) & Mechanical	2.7 (7)	0.0 (0)	6.4 (7)	0.0 (0)
Unsure only	16.6 (43)	6.4 (8)	31.8 (35)	0.0 (0)
Which form(s) of pharmacological prophylaxis has/have the lowest risk of bleeding?†				
LMWH only	57.5 (149)	47.2 (59)	69.1 (76)	58.3 (14)
UFH only	24.7 (64)	32.8 (41)	18.2 (20)	12.5 (3)
LMWH & UFH	5.0 (13)	6.4 (8)	0.0 (0)	20.8 (5)
Unsure only	12.7 (33)	13.6 (17)	12.7 (14)	8.3 (2)
Which form(s) of pharmacological prophylaxis has/have the lowest risk of heparin induced thrombocytopenia?*				

LMWH only	86.1 (223)	94.4 (118)	74.6 (82)	95.8 (23)
UFH only	6.6 (17)	3.2 (4)	11.8 (13)	0.0 (0)
LMWH & UFH	0.4 (1)	0.0 (0)	0.0 (0)	4.2 (1)
Unsure only	7.0 (18)	2.4 (3)	13.6 (15)	0.0 (0)
To what extent do you think best practices are followed for preventing DVT/PE in your ICU? 0=never and 7=always, Median (IQR)				
	6 (5-6)	6 (5-6)	6 (6-7)	6 (5-6)
Survey question	**Overall N=259**	**Physicians/NPs 48.3% (N= 125)**	**Nurses 42.5% (N= 110)**	**Pharmacists 9.3% (N= 24)**
What form(s) of IV fluids is/are most effective for fluid resuscitation?‡				
Albumin only	3.5 (9)	2.4 (3)	5.5 (6)	0.0 (0)
Crystalloids only	84.2 (218)	83.2 (104)	82.7 (91)	95.8 (23)
Albumin & Crystalloids	8.5 (22)	9.6 (12)	9.1 (10)	0.0 (0)
Unsure only	3.9 (10)	4.8 (6)	2.7 (3)	4.2 (1)
Which form(s) of IV resuscitation fluids are most cost effective? ‡				
Albumin only	0.4 (1)	0.0 (0)	0.9 (1)	0.0 (0)
Crystalloids only	94.6 (245)	94.4 (118)	95.5 (105)	91.7 (22)
Albumin & Crystalloids	0.4 (1)	0.8 (1)	0.0 (0)	0.0 (0)
Unsure only	4.6 (12)	4.8 (6)	3.6 (4)	8.3 (2)
Which form(s) of IV resuscitation fluids has the lowest risk of fluid overload? *				
Albumin only	47.1 (122)	32.8 (41)	69.1 (76)	20.8 (5)
Crystalloids only	29.7 (77)	36.8 (46)	23.6 (26)	20.8 (5)
Albumin & Crystalloids	1.9 (5)	3.2 (4)	0.0 (0)	4.2 (1)
Unsure only	21.2 (55)	27.2 (34)	7.3 (8)	54.2 (13)
Which form(s) of IV resuscitation fluids has the lowest risk of infectious disease? ‡				
Albumin only	2.7 (7)	1.6 (2)	4.6 (5)	0.0 (0)
Crystalloids only	86.5 (224)	87.2 (109)	87.3 (96)	79.2 (19)
Albumin & Crystalloids	0.8 (2)	0.8 (1)	0.9 (1)	0.0 (0)
Unsure only	10.0 (26)	10.4 (13)	7.3 (8)	20.8 (5)

To what extent do you think best practices are followed for prescribing fluid boluses in your ICU? 0=never and 7=always; Median (IQR)				
	6 (5-6)	5 (5-6)	6 (5-6)	5 (5-6)

[1]Evidence suggests the efficacy of LMWH for deep vein thrombosis is similar to or better than UFH.[19,20,24,25] Evidence suggests that LMWH is more efficacious than UFH for preventing pulmonary embolism, has a lower incidence of heparin induced thrombocytopenia, and a similar or lower risk of bleeding.[19,20,24,25]
[2]Evidence suggests that LMWH is more cost effective than UFH.[18]
[3]Evidence suggests that albumin and crystalloids are similarly effective for fluid resuscitation.[21, 24, 25, 26] Evidence suggests that albumin has a higher risk of infectious disease transmission than crystalloids and is less cost-effective than crystalloids.
Abbreviations: **IQR** = interquartile range (p25 - p75), **LMWH** = low molecular weight heparin, **N** = number, **NP** = nurse practitioner, **UFH** = unfractionated heparin, ***** = responses varied by professional group (p<0.001), **†** = responses varied by professional group (p=0.01), **‡**= responses did not vary by professional group (p>0.05)

Barriers to adopting LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation

Barriers to adoption and de-adoption were reported by 65.2% and 64.9% of respondents, respectively. The most commonly reported perceived barriers to adopting LMWH for VTE prophylaxis were insufficient knowledge or understanding, ICU culture, and no clinical guidelines (Figure 3). The most commonly reported barriers to de-adopting albumin for fluid resuscitation were a strong clinical preference of the local clinical leaders in the ICUs, ICU culture, and insufficient knowledge or understanding (Figure 3). Reported barriers differed between professional groups for both adoption (Supplemental Content 7) and de-adoption (Supplemental Content 8).

Facilitators to adopting LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation

On site education and pre-set orders were perceived to be the most commonly reported facilitator of both adoption and de-adoption (Figure 4). Verbal reminders from pharmacists to physicians was commonly reported as a perceived facilitator for adopting LWMH for VTE prophylaxis. A local leader championing the practice was commonly reported as a perceived facilitator for de-adopting albumin for fluid resuscitation (Figure 4). There was no variability by professional group.

DISCUSSION

The present study identified opportunities to improve the adoption of an illustrative high value practice (LMWH for VTE prophylaxis) and de-adoption of an illustrative low value practice (albumin for fluid resuscitation). Our audit data demonstrated that practices do not reflect providers' understanding of the evidence for these practices. Both adoption and de-adoption of the illustrative example practices were less likely for patients with greater severity of illness and varied across institutions. The perceived barriers and facilitators to adoption and de-adoption were broadly similar.

Are de-adoption and adoption just the flip-side of the same coin? There is substantial literature describing the adoption of high value practices, but much less is known about de-adoption of low value practices; such that even consistent terminology to describe the process has yet to be agreed upon.[7] Science can inform clinical practice through discovery resulting in adoption of a new practice, replacement resulting in a practice update, and reversal resulting in de-adoption of an existing practice. It is only recently that the last concept, de-adopting low value practices, has been debated in journals and by professional societies.[13,14,16] The practical implication is that there is limited evidence to inform whether the barriers and facilitators for adoption and de-adoption are similar or sufficiently distinct to warrant different approaches.[8,10-12] Our study adds to the limited evidence base by suggesting that culture or organizational factors, provider characteristics, and patient characteristics are perceived to be important barriers and facilitators that may play broadly similar roles in adoption and de-adoption.[10,11]

Knowledge translation (KT) interventions; strategies to improve the synthesis, dissemination, exchange, and application of evidence to improve health,[4] tailored to the specific barriers and facilitators of an innovation and the local context are more likely to effect change.[4,5] Our study provides insight into the perceived barriers and facilitators of adopting high value practices (LMWH for VTE prophylaxis) and de-adopting low value practices (albumin for fluid resuscitation) within ICUs, which should be taken into consideration when designing KT interventions. Interestingly, despite knowledge of the evidence underlying the illustrative example practices, providers perceived insufficient knowledge or understanding to be a barrier and perceived education to be a facilitator to both adopting high value practices and de-adopting low value practices. These barriers and facilitators are consistent with a systematic review that suggests the most effective KT interventions in the ICU employ a combination of education and protocols.[35] While consistent with previous KT studies, this finding is paradoxical. It is possible that while knowledgeable, providers' confidence in applying their knowledge clinically was low and they believed education to be the intervention needed to improve their confidence in applying their knowledge. Furthermore, confidence in applying new evidence in clinical practice may be particularly challenging in the care of severely ill patients. This hypothesis is supported by two of our findings: 1) adoption of LMWH for VTE prophylaxis and de-adoption of albumin for fluid resuscitation was inversely associated with severity of patient illness and 2) adoption of LMWH and de-adoption of albumin increased as the patient became more stable (over ICU stay). Both observations suggest that clinicians may employ conservative decision-making when caring for sicker patients. The implications are

that KT interventions should consider clinician heuristics that are likely to be influenced by the nature and severity of patient illness.

Our study suggests that factors other than knowledge may contribute to the successful adoption of high value practices and de-adoption of low value practices, which includes culture, providers, and the innovation. These factors have previously been identified within the context of the ICU. [36-42] ICU culture and local clinical leader preferences were among the most commonly endorsed barriers to adopting high value practices and de-adopting low value practices in this study and in our study as highlighted by the variation in the adoption of LMWH between sites. Interestingly, this finding was less pronounced for de-adoption, which has been previously reported.[8] Culture, also referred to as organizational context, is a frequently cited barrier to evidence-based medicine and can have a profound effect on clinical practice.[6,43] However, few studies have systematically evaluated the effect of culture on adopting high value practices and de-adopting low value practices, and implementation studies infrequently account for the effect of culture on their practice change interventions.[44] Similarly, the professional role of the provider is not often contextualized but may be important (e.g., should pharmacists and nurses be targeted in KT interventions designed to change the prescribing patterns of physicians and if so how?).[45] This may be especially relevant as healthcare delivery becomes increasingly multi-professional and team-based as illustrated in our setting (ICU).

The characteristics of innovations themselves may influence change in clinical practice. Evidence suggests that if the innovation being adopted is congruent with clinical practice beliefs it can facilitate adoption.[6] Furthermore, the quality, quantity, and stability of available evidence to support the adoption or de-adoption of an innovation is likely important.[46] Although most providers in our study were aware of the evidence to support the adoption of LMWH for VTE prophylaxis and de-adoption of albumin for fluid resuscitation, they may not have perceived the evidence to be sufficient to warrant practice change. A growing awareness of challenges with reproducing scientific evidence and clinician experience with practice reversals[42] may result in more conservative provider behavior and slower practice change in response to new evidence. The suboptimal prescribing practices observed in our study likely represent a combination of all these factors.

One limitation of this study is the use of an electronic medical record as the data source, which provides population-based data, but may not capture all possible indications for the failure to adopt high value practices and the use of low value practices (i.e., patient, provider, and organizational factors). Secondly, the survey used in this study is imperfect. The results of the self-reported survey reflect perceived modifiers of practice among providers who had knowledge of the evidence underpinning these two illustrative example practices, rather than factors shown to influence practice patterns as identified in observational studies.[47] The survey was purposefully designed to be simple and accessible to garner a representative perspective from all provider professions and therefore lacks granularity.

Nevertheless, the survey has been successfully used for a similar purpose by others;[33] was reliable and reported to have good clinical sensibility. Thirdly, while this study was a provincial and multi-site it was constrained to ICUs, which should be taken into consideration when interpreting our findings beyond this setting.

In conclusion, our study provides several insights into similarities and differences between adoption of high value practices and de-adoption of low value practices. Both adoption and de-adoption of the illustrative practices did not reflect healthcare providers' knowledge of the evidence. Both adoption and de-adoption of the were less likely for patients with greater severity of illness and varied across institutions. We found that perceived barriers and facilitators are more similar than different between adoption and de-adoption, which suggests existing behavior change frameworks for adopting high value practices may also be applicable for de-adopting low value practices.

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DISCLOSURE OF CONFLICT OF INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

Dr. Sauro contributed to the design and conceptualization of the study; analysis and interpretation of the data, drafting and revising the manuscript and gave approval of the final version of the manuscript. No conflicts of interest to declare.

Dr. Bagshaw contributed to the design and conceptualization of the study, interpretation of the data, providing feedback on the manuscript, and gave approval of the final version of the manuscript. No conflicts of interest to declare.

Dr. Niven contributed to the design and conceptualization of the study, interpretation of the data, providing feedback on the manuscript, and gave approval of the final version of the manuscript. No conflicts of interest to declare.

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Ms. Brundin-Mather contributed to the interpretation of the data, providing feedback on the manuscript, and gave approval of the final version of the manuscript. No conflicts of interest to declare.

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Dr. Stelfox contributed to the design and conceptualization of the study, interpretation of the data, providing feedback on the manuscript, and gave approval of the final version of the manuscript. No conflicts of interest to declare.

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Figure 1. The flow of patients into the ICU and into the adoption and de-adoption cohorts.

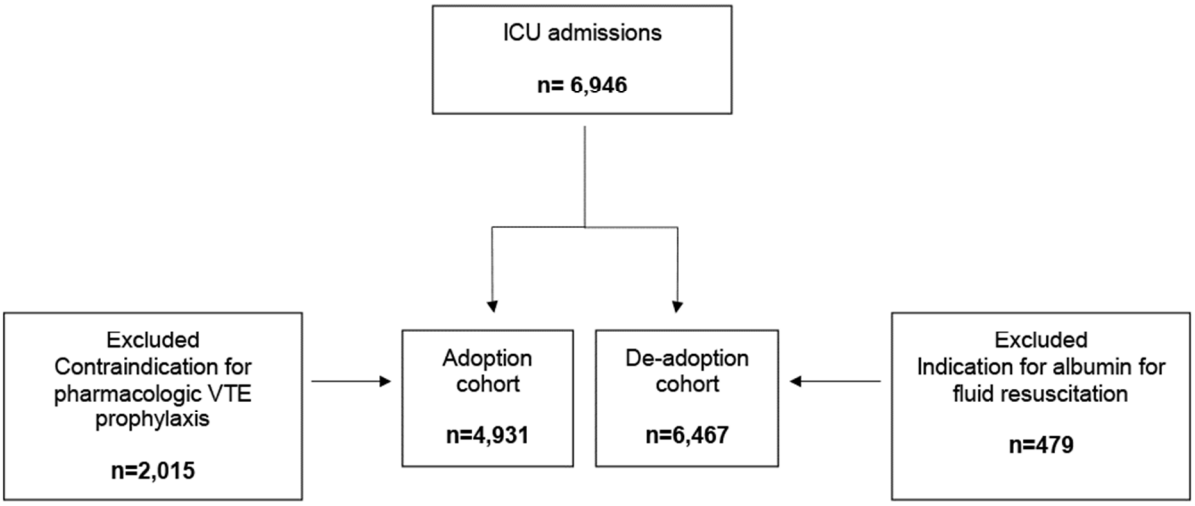
Abbreviations: ICU: intensive care unit; VTE: venous thromboembolism; LMWH: low molecular weight heparin

Figure 2. The proportion of patients receiving mechanical, unfractionated, and low molecular weight heparin for venous thromboembolism prophylaxis over time (by intensive care unit patient day).

Figure 3. Barriers to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation)

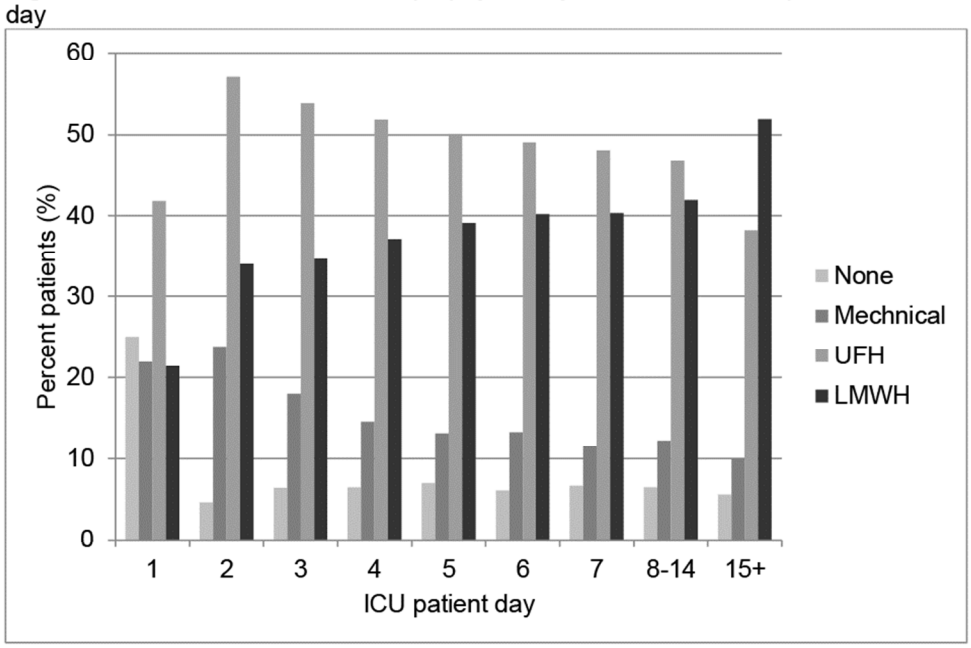
Figure 4. Facilitators to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation).

Figure 1. Flow of patients



Footnote: Adoption cohort = Recommended to receive LMWH for VTE prophylaxis; de-adoption cohort = Recommended to NOT receive albumin for fluid resuscitation

Figure 1. Venous thromboembolism prophylaxis by intensive care unit patient day



Footnote: Percent of patients may add to greater than 100% because patients may have received more than one form of venous thromboembolism prophylaxis on a given patient day.
Abbreviation: ICU=intensive care unit, LMWH=low molecular weight heparin, UFH=unfractionated heparin

Figure 3. Barriers to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation)

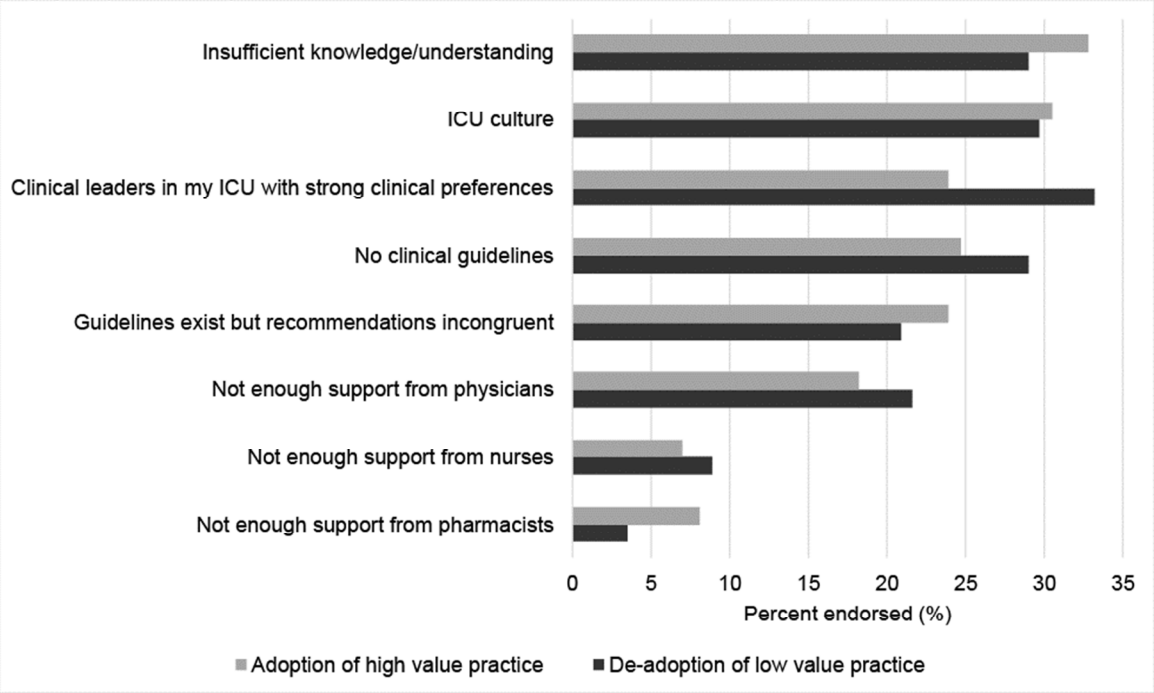
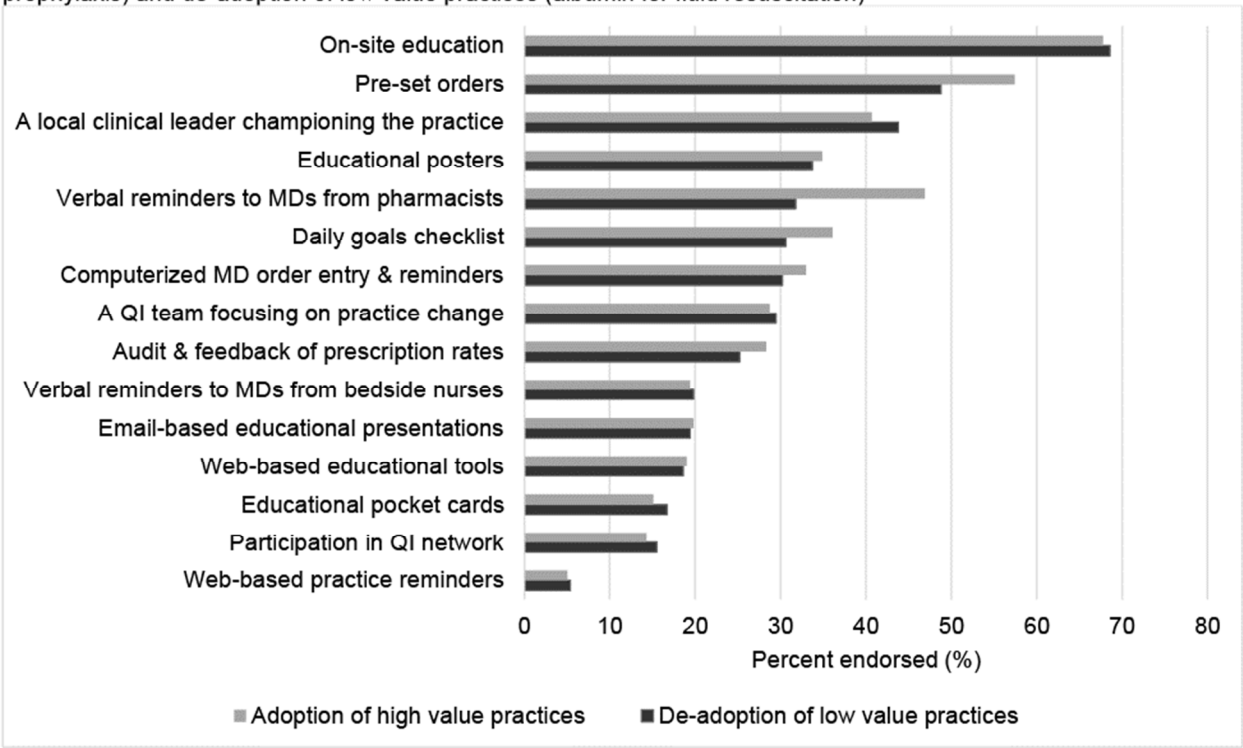


Figure 4. Facilitators to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation)



Abbreviation: **MD=**medical doctor, **QI=**quality improvement

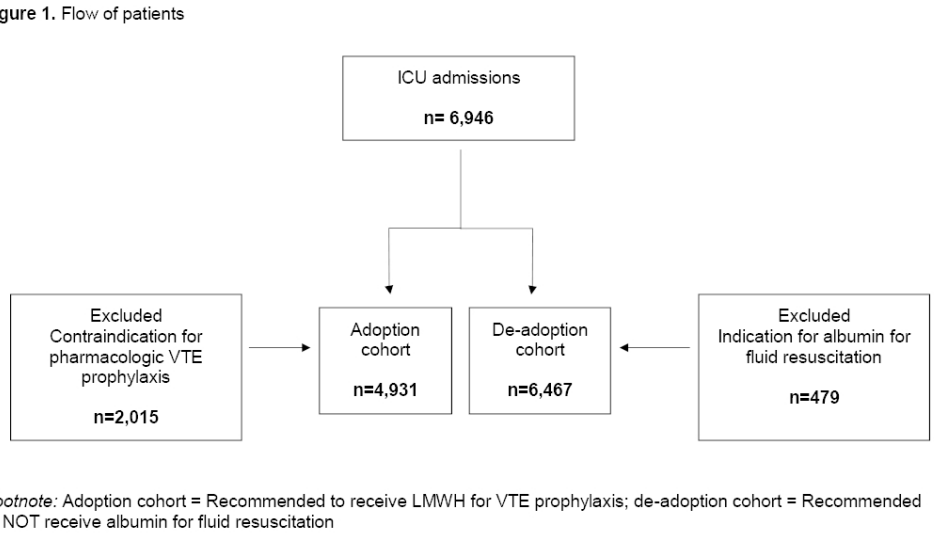
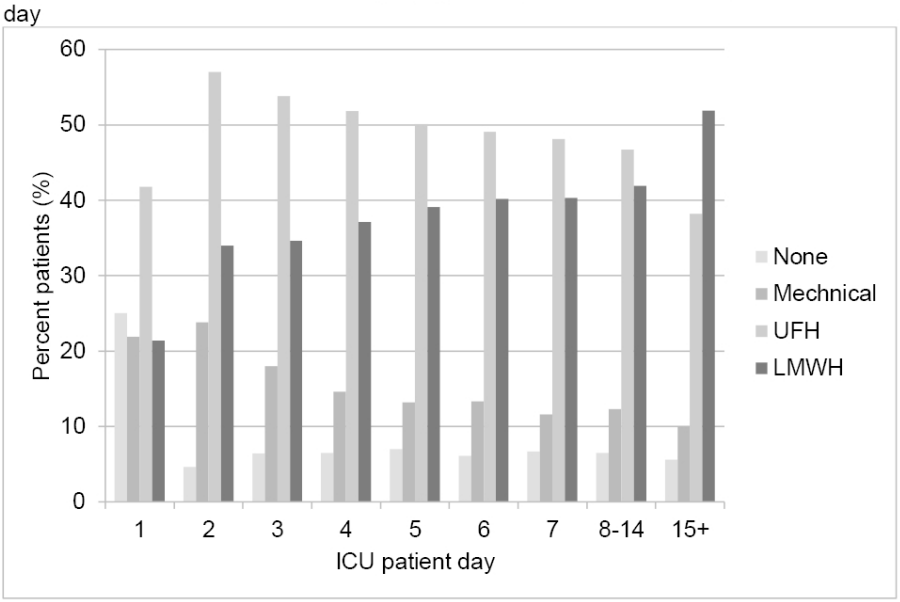


Figure 1. The flow of patients into the ICU and into the adoption and de-adoption cohorts. Abbreviations: ICU: intensive care unit; VTE: venous thromboembolism; LMWH: low molecular weight heparin

90x50mm (300 x 300 DPI)

Figure 1. Venous thromboembolism prophylaxis by intensive care unit patient day



Footnote: Percent of patients may add to greater than 100% because patients may have received more than one form of venous thromboembolism prophylaxis on a given patient day.
Abbreviation: ICU=intensive care unit, LMWH=low molecular weight heparin, UFH=unfractionated heparin

Figure 2. The proportion of patients receiving mechanical, unfractionated, and low molecular weight heparin for venous thromboembolism prophylaxis over time (by intensive care unit patient day).

90x80mm (300 x 300 DPI)

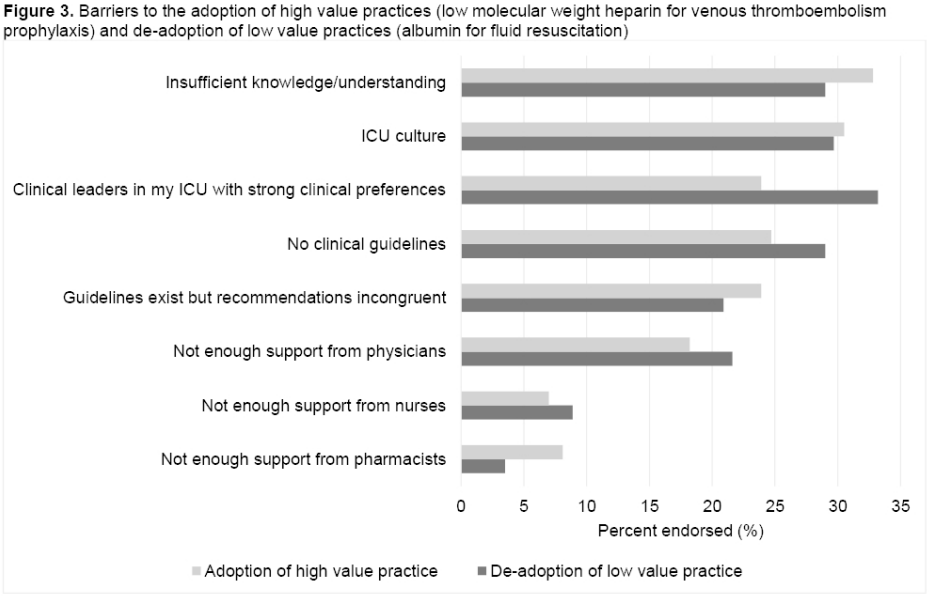


Figure 3. Barriers to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation)

90x60mm (300 x 300 DPI)

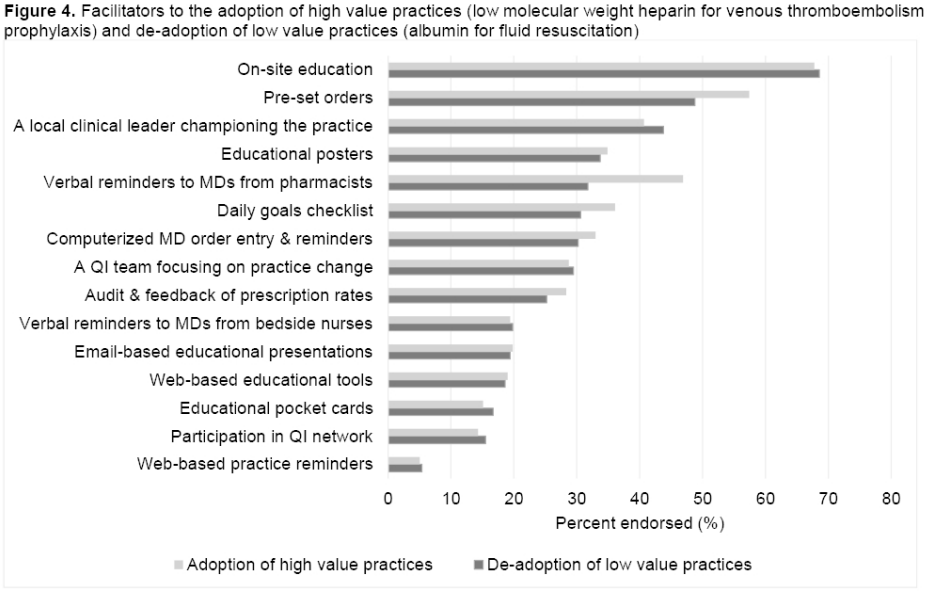


Figure 4. Facilitators to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation).

90x63mm (300 x 300 DPI)

Supplemental Digital Content 1. List of diagnoses with a potential contraindication to receive pharmacological venous thromboembolism prophylaxis or indication for therapeutic anticoagulation*

Arteriovenous malformation, surgery for
Embolus, pulmonary
GI Vascular insufficiency
Grafts, removal of infected vascular
Neoplasm, neurologic
Neoplasm-cranial, surgery for (excluding transphenoidal)
Neoplasm-spinal cord surgery or other related procedures
Neurologic surgery, other
Subarachnoid hemorrhage/intracranial aneurysm
Subarachnoid hemorrhage/intracranial aneurysm, surgery for
Thrombosis, vascular (deep vein)
Transphenoidal surgery
Ulcer disease, peptic
Abdomen only trauma
Abdomen only trauma, surgery for
Abdomen/extremity trauma
Abdomen/extremity trauma, surgery for
Abdomen/face trauma
Abdomen/face trauma, surgery for
Abdomen/multiple trauma
Abdomen/multiple trauma, surgery for
Abdomen/pelvis trauma, surgery for
Abscess/infection-cranial, surgery for
Anastomosis, vascular
Aneurysm, abdominal aortic
Aneurysm, abdominal aortic; with dissection
Aneurysm, abdominal aortic; with rupture
Aneurysm, dissecting aortic
Aneurysm, thoracic aortic
Aneurysm, thoracic aortic; with dissection
Aneurysm, thoracic aortic; with rupture
Aneurysm/pseudoaneurysm, other
Aneurysms, repair of other (except ventricular)
Biopsy, brain
Bleeding, GI from esophageal varices/portal hypertension
Bleeding, GI-location unknown
Bleeding, lower GI
Bleeding, upper GI
Bleeding-lower GI, surgery for
Bleeding-other GI, surgery for
Bleeding-upper GI, surgery for

Burr hole placement
CABG alone, coronary artery bypass grafting
CVA, cerebrovascular accident/stroke
Chest/abdomen trauma
Chest/abdomen trauma, surgery for
Chest/extremity trauma
Chest/extremity trauma, surgery for
Chest/face trauma
Chest/face trauma, surgery for
Chest/multiple trauma
Chest/multiple trauma, surgery for
Chest/pelvis trauma
Chest/pelvis trauma, surgery for
Chest/spinal trauma
Chest/spinal trauma, surgery for
Chest/thorax only trauma
Chest/thorax only trauma, surgery for
Coagulopathy
Complications of prev. peripheral vasc. surgery, surgery for (i.e.ligation of bleeder, exploration and evacuation of hematoma, debridement, pseudoaneurysms, clots, fistula, etc.)
Complications of previous GI surgery; surgery for (anastomotic leak, bleeding, abscess, infection, dehiscence, etc.)
Complications of previous spinal cord surgery, surgery for
Cranioplasty and complications from previous craniotomies
Head (CNS) only trauma
Head (CNS) only trauma, surgery for
Head/abdomen trauma
Head/abdomen trauma, surgery for
Head/chest trauma
Head/chest trauma, surgery for
Head/extremity trauma
Head/extremity trauma, surgery for
Head/face trauma
Head/face trauma, surgery for
Head/multiple trauma
Head/multiple trauma, surgery for
Head/pelvis trauma
Head/pelvis trauma, surgery for
Head/spinal trauma
Head/spinal trauma, surgery for
Hematoma, epidural
Hematoma, epidural, surgery for
Hematoma, subdural
Hematoma, subdural, surgery for

Hematomas
Hemorrhage (for gastrointestinal bleeding GI-see GI system) (for trauma see Trauma)
Hemorrhage, intra/retroperitoneal
Hemorrhage, postpartum (female only)
Hemorrhage/hematoma, intracranial
Hemorrhage/hematoma-intracranial, surgery for
Hemorrhage/hemoptysis, pulmonary
Hemothorax
Pelvis/extremity trauma
Pelvis/extremity trauma, surgery for
Pelvis/face trauma
Pelvis/hip only trauma, surgery for
Pelvis/multiple trauma, surgery for
Pelvis/spinal trauma
Pericardial effusion/tamponade
Renal bleeding
Spinal cord only trauma, surgery for
Spinal cord surgery, other
Stereotactic procedure
Subarachnoid hemorrhage/arteriovenous malformation
Tamponade, pericardial

**Footnote:* The primary diagnoses were reviewed independently by two ICU physicians (HTS, DJN). The two ICU physicians provided their judgment to establish a conservative list of primary diagnoses in order to exclude patients that may have a contraindication for pharmacological VTE prophylaxis based on bleeding risk and an indication for therapeutic anticoagulation. Discrepancies were resolved by discussion.

Adopting Best Practices in DVT/PE Prophylaxis and Fluid Resuscitation in Critical Care

http://fluidsurveys.com/s/ECG_faciliatators_barriers_survey/

Informed Consent

This survey is to identify and evaluate barriers to, and facilitators of, best practices in:

1. Deep Vein Thrombosis (DVT) / Pulmonary Embolism (PE) prophylaxis for medical-surgical ICU patients, and
2. Fluid Resuscitation for medical-surgical ICU patients *without* liver disease, bacterial peritonitis, hepatorenal syndrome or therapeutic paracentesis.

This survey is not about trauma, neurosurgery or cardiac surgery patients. Survey responses will be used to develop interventions to facilitate the adoption of best practices in Alberta ICUs.

You are being asked to take part in this survey because you are a healthcare professional working in adult critical care in Alberta. Our survey can be answered in approximately **5 minutes**. There are no direct benefits and/or risks to your participation.

Survey respondents can choose to have their name entered into a draw for *$20 Starbucks gift cards* (one name will be drawn per week; non-winners will remain in the draw each week).

Your participation in this survey is voluntary and you are free to stop at any time. Your responses will be kept confidential. Your de-identified data will be stored in a password-protected database, and responses will only be presented in aggregate. The survey has peer-reviewed funding and has received ethics approval from the University of Calgary. **Your decision to complete and submit this survey will indicate your consent to participate**. Should you decide to withdraw your participation before submitting the survey, your data will be deleted.

If you have questions about this survey or your participation, please contact:
Rebecca Brundin-Mather, Research Coordinator, at brundin@ucalgary.ca.

If you have questions about your rights as a participant, you may contact the University of Calgary Conjoint Research Ethics Board at (403) 220-7990. This office is not affiliated with the study team.

Thank you in advance for taking the time to complete the survey!

Kind regards,

Tom Stelfox, MD, PhD, FRCPC
Intensive Care Physician
Scientific Director, AHS, Critical Care Strategic Clinical Network

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○ I agree to participate in this survey ○ I do **NOT** wish to participate in this survey (online-version)

Demographics

1. What is your professional group?

○ ICU physician	○ Nurse Clinician	○ Pharmacist
○ ICU resident	○ Nurse Educator	○ Other: _____
○ ICU fellow	○ Bedside Nurse	

2. Approximately how many years have you worked in:

Health care ☐ Critical care ☐

3. In which hospital(s) do you primarily work? (Select all that apply)

- ○ Chinook Regional Hospital
- ○ Foothills Medical Centre
- ○ Grand Praire QE II Hospital
- ○ Grey Nuns Hospital
- ○ Medicine Hat Regional Hospital
- ○ Misericordia Hospital
- ○ Northern Lights Regional Health Centre
- ○ Peter Lougheed Centre
- ○ Red Deer Regional Hospital
- ○ Rockyview General Hospital
- ○ Royal Alexander Hospital
- ○ South Health Campus
- ○ Sturgeon Community Hospital
- ○ University of Alberta Hospital

DVT/PE Prevention

We are interested in your perceptions of the different forms of prophylaxes commonly used to prevent Deep Vein Thrombosis (DVT) and Pulmonary Embolism (PE) in medical-surgical ICU patients (not trauma, neurosurgery or cardiac surgery patients). Common prophylaxes include:

- Low molecular weight heparin (**LMWH** e.g., Enoxaparin, Dalteparin, Tinzaparin)
- Unfractionated heparin (**UFH**, regular Heparin)
- **Mechanical** prophylaxis (i.e., sequential compression devices)

We appreciate that practices vary across units and providers. For each of the following questions, please select the **best response option** OR **options**, to the best of your knowledge (more than one response option can be selected).

4. Which form(s) of prophylaxis is/are most effective at preventing:

	LMWH	UFH	Mechanical	Unsure
Deep Vein Thrombosis (DVT)	☐	☐	☐	☐
Pulmonary Embolism (PE)	☐	☐	☐	☐

5. Which form(s) of prophylaxis is/are most cost-effective?

LMWH	UFH	Mechanical	Unsure
☐	☐	☐	☐

6. Which form(s) of *pharmacological* prophylaxis has/have the lowest risk of:

	LMWH	UFH	Unsure
Bleeding	☐	☐	☐
Heparin Induced Thrombocytopenia (HIT)	☐	☐	☐

7. To what extent do you think best practices for preventing DVT/PE are followed **in your ICU** (i.e., the patient receives the right prophylaxis with the right dose at the right time)?

○	○	○	○	○	○	○	○
1	**2**	**3**	**4**	**5**	**6**	**7**	Unsure
Never			**Sometimes**			**Always**	

Intravenous Fluid Resuscitation

We are now interested in your perceptions of the different types of intravenous fluids commonly used for fluid resuscitation (i.e., fluid boluses) in the ICU for medical-surgical patients, **excluding** patients with liver disease, bacterial peritonitis, or undergoing therapeutic paracentesis as they may have different fluid needs. Common resuscitation fluids include:

- **Human Albumin** (Albumin 5% or Albumin 25%)
- **Crystalloid solutions** (e.g., normal saline, ringers lactate, and plasma-lyte)

Again, we appreciate that clinical practices vary across units and providers. For each of the following questions, please select the **best response option** OR **options**, to the best of your knowledge (more than one response option can be selected).

8. Which form(s) of IV resuscitation fluid is/are most effective for resuscitation?

Albumin ☐ Crystalloids ☐ Unsure ☐

9. Which form(s) of IV resuscitation fluid(s) is/are most cost-effective?

Albumin ☐ Crystalloids ☐ Unsure ☐

10. Which form(s) of IV resuscitation fluid(s) has/have the lowest risk of:

	Albumin	Crystalloids	Unsure
Fluid overload (peripheral / pulmonary)	☐	☐	☐
Contracting an infectious disease	☐	☐	☐

11. To what extent do you think *best practices* for prescribing fluid boluses are followed **in your ICU** (i.e., the patient receives the right fluid with the right dose at the right time)?

○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ Unsure
Never			**Sometimes**			**Always**	

Barriers to Best Practices

A number of ICU or 'systems' factors have been identified as potential barriers to best practices. We are interested in what you think are barriers **in your ICU** to prescribing:

1. LMWH over UFH for DVT/PE prophylaxis
2. Crystalloid solutions over Albumin for fluid resuscitation

12. Which of the following factors are current barriers in your ICU to prescribing…

	LMWH over UFH		Crystalloids over Albumin	
	Current Barrier	Unsure	Current Barrier	Unsure
An ICU culture with an unclear or slow process for practice change	○	○	○	○
Not enough support from physicians	○	○	○	○
Not enough support from nurses	○	○	○	○
Not enough support from pharmacists	○	○	○	○
Clinical leaders in my ICU with strong clinical preferences	○	○	○	○
No clinical guidelines or orders sets in my ICU to guide the practice	○	○	○	○
Guidelines exist in my ICU, but they do not recommend LWMH over UFH / crystalloids over albumin	○	○	○	○
Insufficient knowledge/understanding the evidence base for the practice.	○	○	○	○
None of the above factors are current barriers in my ICU to prescribing….	○		○	
Please note any other factors that may be barriers to prescribing LMWH over UFH and/or crystalloids over albumin. Specify below.				

Strategies to Encourage Best Practices

A number of strategies have been identified as potential facilitators to changing clinical practice. We are interested in your perceptions of different strategies that have been used to encourage:

1. LMWH over UFH for DVT/PE prophylaxis
2. Crystalloid solutions over Albumin for fluid resuscitation

13. Which of the following strategies are currently used in your ICU to encourage…

	LMWH over UFH	Crystalloids over Albumin
1. On-site education (in-services, rounds, journal clubs, orientations)	○	○
2. Educational posters (in the unit)	○	○
3. Educational pocket cards	○	○
4. Email-based educational presentations	○	○
5. Web-based educational tools	○	○
6. Verbal reminders to physicians from pharmacists	○	○
7. Verbal reminders to physicians from bedside nurses	○	○
8. Pre-set orders	○	○
9. Computerized physician order entry & reminders	○	○
10. Web-based practice reminders	○	○
11. Daily goals checklist	○	○
12. Audit & feedback of prescription rates	○	○
13. A quality improvement team focusing on practice change	○	○
14. Participation in a quality improvement network	○	○
15. A local clinical leader championing the practice	○	○
16. Other strategy used. Please specify:	○	○
17. Other strategy used. Please specify:	○	○
NO strategies are currently being used in my ICU encourage this practice:	○	○

14. From the same list of strategies, please select the **5 best strategies** that you believe would work **in your ICU** to encourage:
    (1) LMWH over UFH for DVT/PE prophylaxis
    (2) Crystalloid solutions over Albumin for fluid resuscitation
    (Select up to **5 strategies**, regardless whether the strategy is used in your ICU or not)

Select up to 5 in each column

Strategy to change clinical practice	LMWH over UFH	Crystalloids over Albumin
1. On-site education (in-services, rounds, journal clubs, orientations)	☐	☐
2. Educational posters (in the unit)	☐	☐
3. Educational pocket cards	☐	☐
4. Email-based educational presentations	☐	☐
5. Web-based educational tools	☐	☐
6. Verbal reminders to physicians from pharmacists	☐	☐
7. Verbal reminders to physicians from bedside nurses	☐	☐
8. Pre-set orders	☐	☐
9. Computerized physician order entry & reminders	☐	☐
10. Web-based practice reminders	☐	☐
11. Daily goals checklist	☐	☐
12. Audit & feedback of prescription rates	☐	☐
13. A quality improvement team to focus on practice change	☐	☐
14. Participation in a quality improvement network	☐	☐
15. A local clinical leader to champion the practice	☐	☐
16. Other strategy. Please specify:	☐	☐
17. Other strategy. Please specify:	☐	☐

15. Finally, please provide any additional comments in the text box below.

Please select the check box(es) below to have your name entered in the Starbucks coffee card draws and/or to receive the study results.

☐ Yes, I would like my name entered in the coffee card draws.

☐ Yes, I would like to receive the results from this study.

My email address is:

N.B. E-mail addresses will be kept confidential and will not be used to contact you for any reason other than those noted above.

---End of Survey ---

Thank you for helping us improve care!

Please return completed surveys to:

Dr. Tom Stelfox
Department of Critical Care Medicine
Foothills Medical Centre

OR

Rebecca Brundin-Mather
Ward of the 21st Century
GD01 Teaching, Research, Wellness Bldg
University of Calgary, 3280 Hospital Dr NW
Calgary, AB T2N 4Z6

Supplemental Digital Content 3. Intensive care unit patient characteristics for the study period (January 1, 2014-December 31, 2014)

Demographic variable	Population (N=6,946)	Adoption cohort 70.7% (N=4,931)	De-adoption cohort 93.1% (N=6,467)
Age, median (IQR)	60 (46-71)	61 (47-71)	61 (46-71)
Female	41.6 (2,888)	43.3 (2,134)	41.8 (2,703)
Comorbidities			
AIDS	0.6 (42)	0.7 (33)	0.5 (35)
Chronic dialysis	3.5 (240)	3.8 (186)	3.5 (225)
Chronic heart failure	6.4 (444)	7.4 (364)	6.5 (419)
Cirrhosis	5.9 (407)	6.0 (294)	0.0 (0)
Diabetes	19.7 (1,366)	21.6 (1,065)	19.9 (1,284)
Hepatic failure	3.9 (269)	4.1 (203)	0.0 (0)
Immune suppression	8.5 (589)	9.4 (463)	8.2 (532)
Leukemia or multiple myeloma	1.3 (88)	1.4 (69)	1.3 (86)
Lymphoma	1.1 (77)	1.2 (61)	1.2 (75)
Metastatic cancer	3.9 (272)	4.1 (203)	4.1 (262)
Respiratory insufficiency	12.0 (833)	14.6 (722)	12.5 (810)
Any comorbidity	44.6 (3,100)	49.3 (2,431)	40.6 (2,625)
Admitted from			
Emergency department	36.6 (2,540)	36.7 (1,808)	36.5 (2,358)
Operating / recovery room	21.9 (1,520)	18.3 (902)	22.2 (1,437)
Hospital ward	26.7 (1,858)	28.1 (1,386)	26.3 (1,702)
Other hospital	10.4 (722)	11.9 (589)	10.5 (677)
Other location	4.3 (300)	4.9 (243)	4.5 (288)
Unknown	0.1 (6)	0.1 (3)	0.1 (5)
Admission type			

Elective surgery	9.4 (655)	8.1 (399)	9.5 (614)
Emergent surgery	16.8 (1,170)	13.8 (681)	17.3 (1,120)
No surgery	73.1 (5,078)	78.1 (3,851)	72.5 (4,690)
Unknown	0.6 (43)	0.0 (0)	0.7 (43)
Reason for ICU admission			
Medical	59.9 (4,163)	69.4 (3,420)	58.7 (3,797)
Surgical	25.8 (1,789)	24.1 (1,190)	26.2 (1,696)
Neurological	9.3 (649)	4.1 (200)	9.8 (632)
Trauma	4.3 (302)	2.5 (121)	4.6 (299)
Unknown	0.6 (43)	0.0 (0)	0.7 (43)
APACHE II Score on ICU admission, median (IQR)	19 (14-26)	20 (15-26)	19 (14-25)
Glasgow Coma Scale score on ICU admission, median (IQR)	14 (11-15)	14 (11-15)	14 (11-15)
Intubation	65.5 (4,553)	66.2 (3,264)	64.9 (4,195)
Invasive ventilation	68.3 (4,747)	68.8 (3,393)	67.8 (4,387)
Duration, median hours (IQR)	51 (18-133)	62 (25-143)	50 (18-132)
Non-invasive ventilation	13.1 (913)	16.2 (798)	13.6 (878)
Duration, median hours (IQR)	24 (8-63)	28 (9-68)	24 (6-65)
ICU length of stay, median days (IQR)	3.7 (1.8-7.7)	4.3 (2.4-8.3)	3.7 (1.8-7.6)
Hospital length of stay, median days (IQR)	13.3 (6.1-29.5)	13.9 (6.8-30.0)	13.2 (6.1-29.3)
ICU mortality	14.1 (981)	12.2 (601)	12.9 (837)
Hospital mortality	21.0 (1,462)	19.9 (979)	19.5 (1,260)

Abbreviations: **AIDS**=autoimmune deficiency syndrome, **APACHE II**=Acute Physiology and Chronic Health Evaluation II, **ICU**=intensive care unit, **IQR**=interquartile range,

Supplemental Digital Content 4. Association between demographic and site-level factors, and adoption and de-adoption

	Adoption cohort OR (95% CI)*	De-adoption cohort OR (95% CI)**
Age	NS†	0.999 (0.999-1.00)
Female	NS†	NS†
Any comorbidity	NS†	NS†
Admission type		
Elective surgery	1.00 (reference group)	1.00 (reference group)
Emergent surgery	1.19 (0.92-1.53)	0.92 (0.88-0.95)
No surgery	1.34 (1.08-1.66)	1.02 (0.98-1.05)
APACHE II Score on ICU admission	0.958 (0.951-0.965)	0.989 (0.988-0.990)
Site		
C1	1.00 (reference group)	1.00 (reference group)
C2	1.32 (1.07-1.64)	0.96 (0.92-1.00)
C3	1.13 (0.89-1.46)	0.98 (0.94-1.03)
C4	1.48 (1.15-1.90)	0.98 (0.93-1.02)
E1	2.12 (1.66-2.73)	0.90 (0.86-0.95)
E2	0.86 (0.71-1.05)	0.90 (0.87-0.92)
E3	7.26 (5.46-9.65)	0.92 (0.87-0.97)
E4	0.76 (0.63-0.92)	0.88 (0.85-0.91)
E5	1.61 (1.23-2.10)	0.75 (0.72-0.79)

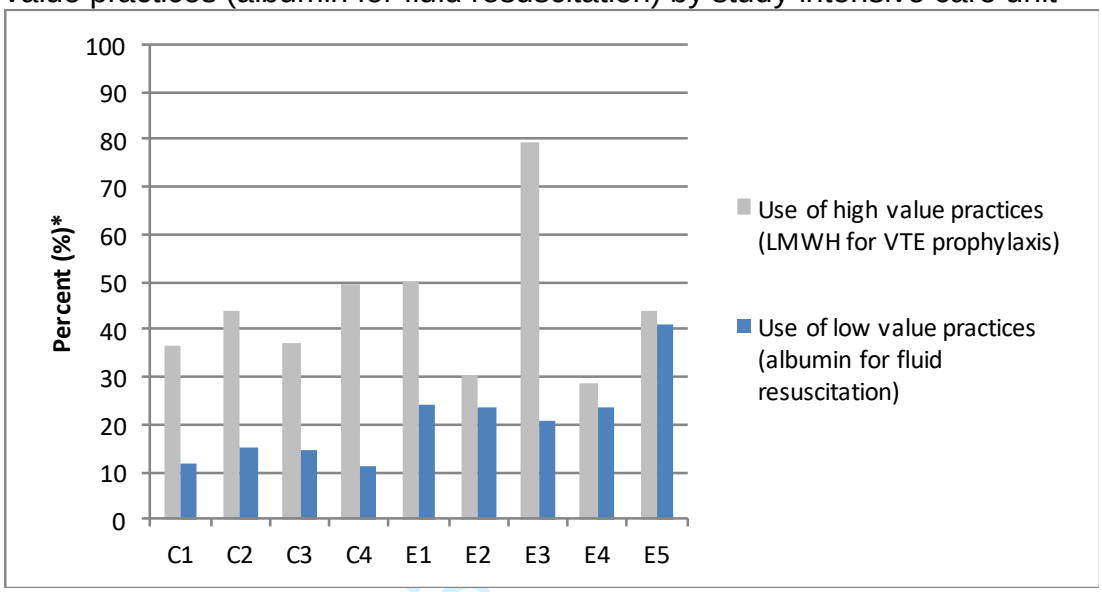
Footnote: all "C" sites indicate ICU in Calgary and all "E" sites indicate ICU in Edmonton

*Used a multivariable generalized estimating equations (GEEs) logistic regression model with exchangeable correlation structure given daily measurements (clustering by patient); appropriate use considered "use of LMWH"

**Used standard multivariable logistic regression model given single measurement per patient; "appropriate use" considered "not using albumin"

†NS = non-significant, removed from model

Supplemental Digital Content 5. The use of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and the use of low value practices (albumin for fluid resuscitation) by study intensive care unit



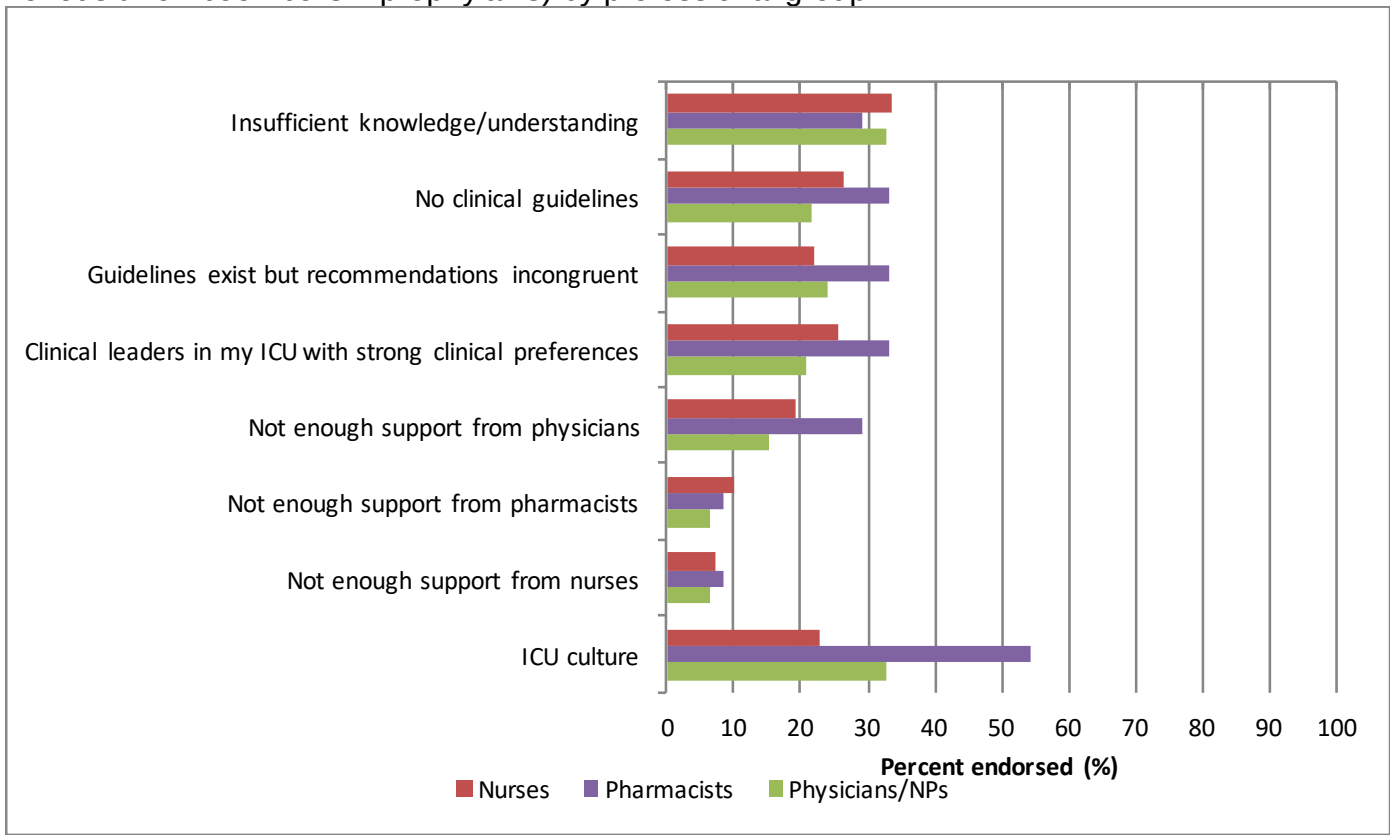
Footnote: all "C" sites indicate ICU in Calgary and all "E" sites indicate ICU in Edmonton

*% of patient-days for VTE prophylaxis and % of patients for albumin

Supplemental Digital Content 6. Survey participant characteristics

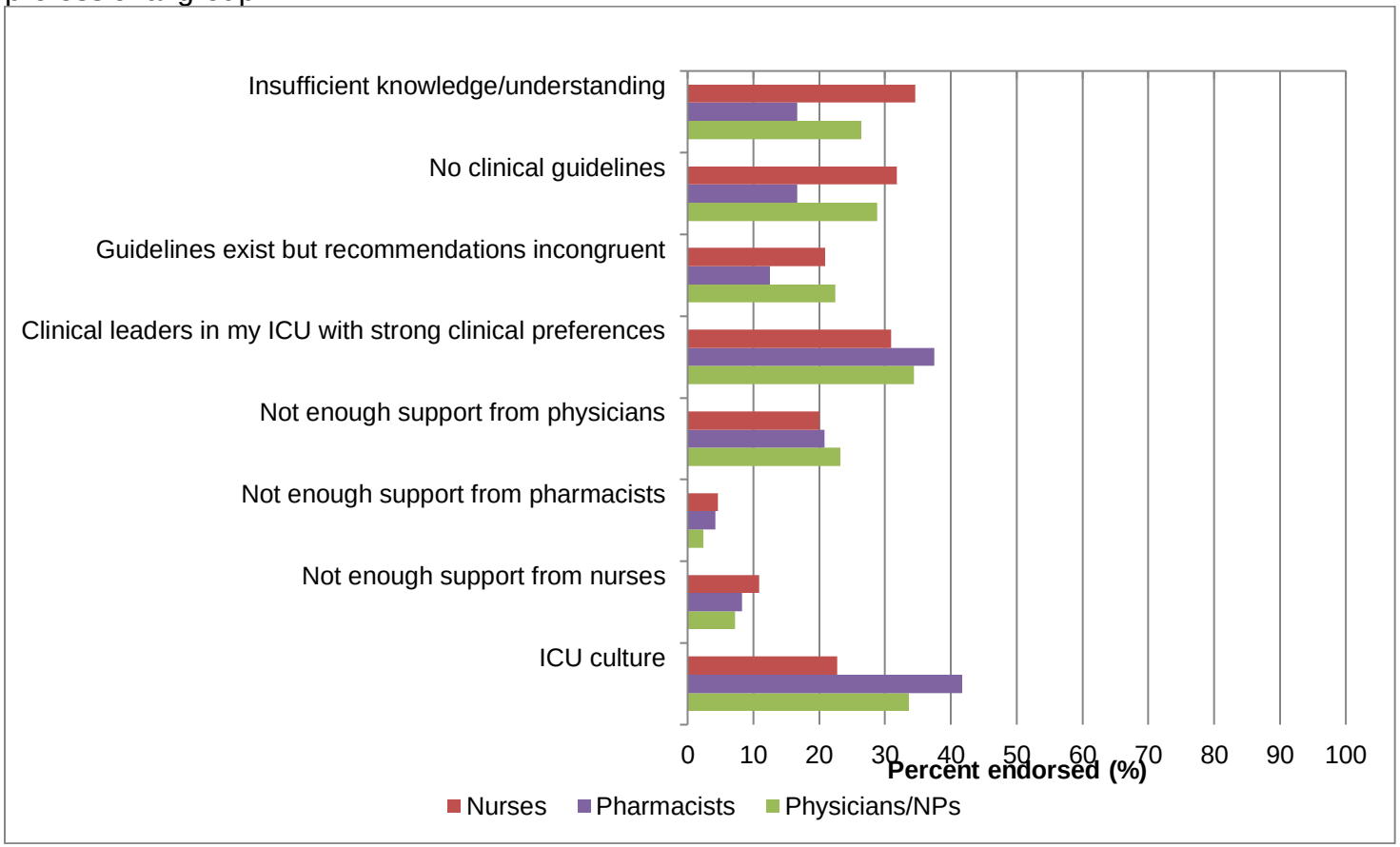
Professional group	**% (N)**
Attending physician	24.7 (64)
Fellow	6.2 (16)
Resident	12.4 (32)
Nurse practitioner	5.0 (13)
Nurse manager / charge nurse	10.0 (26)
Nurse educator	8.5 (22)
Bedside nurse	23.9 (62)
Pharmacist	9.3 (24)
Years worked in ICU	Median (IQR)
Attending physician	14.0 (9.8-22.0)
Clinical fellow	1.8 (1.0-2.3)
Resident	0.3 (0.1-1.0)
Nurse practitioner	15.0 (9.0-20.0)
Nurse manager / charge nurse	11.5 (7.3-18.8)
Nurse educator	19.0 (10.3-21.5)
Bedside nurse	7.5 (2.5-12.0)
Pharmacist	5.3 (3.0-10.8)
Years worked in healthcare	Median (IQR)
Attending physician	19.0 (14.8-25.3)
Clinical fellow	8.0 (7.0-9.5)
Resident	3.0 (2.0-5.1)
Nurse practitioner	15.0 (12.0-25.0)
Nurse manager / charge nurse	16.5 (12.5-24.0)
Nurse educator	21.0 (13.0-26.0)
Bedside nurse	10.0 (6.0-16.0)
Pharmacist	10.5 (6.1-14.3)

Supplemental Digital Content 7. Barriers to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) by professional group



Abbreviations: **ICU**=intensive care unit, **NP**=nurse practitioner

Supplemental Digital Content 8. Barriers to the de-adoption of low value practices (albumin for fluid resuscitation) by professional group



Abbreviations: **ICU**=intensive care unit, **NP**=nurse practitioner

Reporting checklist for quality improvement study.

Based on the SQUIRE guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

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		Reporting Item	Page Number
	#1	Indicate that the manuscript concerns an initiative to improve healthcare (broadly defined to include the quality, safety, effectiveness, patientcenteredness, timeliness, cost, efficiency, and equity of healthcare)	1
	#02a	Provide adequate information to aid in searching and indexing	3
	#02b	Summarize all key information from various sections of the text using the abstract format of the intended publication or a structured summary such as: background, local problem, methods, interventions, results, conclusions	2 & 3
Problem description	#3	Nature and significance of the local problem	5
Available knowledge	#4	Summary of what is currently known about the problem, including relevant previous studies	4 & 5
Rationale	#5	Informal or formal frameworks, models, concepts, and / or theories used to explain the problem, any reasons or	5 & 6

		assumptions that were used to develop the intervention(s), and reasons why the intervention(s) was expected to work	
Specific aims	#6	Purpose of the project and of this report	5 & 6
Context	#7	Contextual elements considered important at the outset of introducing the intervention(s)	6
Intervention(s)	#08a	Description of the intervention(s) in sufficient detail that others could reproduce it	N/A
	#08b	Specifics of the team involved in the work	10
Study of the Intervention(s)	#09a	Approach chosen for assessing the impact of the intervention(s)	8-11
	#09b	Approach used to establish whether the observed outcomes were due to the intervention(s)	8-11
Measures	#10a	Measures chosen for studying processes and outcomes of the intervention(s), including rationale for choosing them, their operational definitions, and their validity and reliability	7,8,10
	#10b	Description of the approach to the ongoing assessment of contextual elements that contributed to the success, failure, efficiency, and cost	7-10
	#10c	Methods employed for assessing completeness and accuracy of data	7-11
Analysis	#11a	Qualitative and quantitative methods used to draw inferences from the data	8-11
	#11b	Methods for understanding variation within the data, including the effects of time as a variable	8-11
Ethical considerations	#12	Ethical aspects of implementing and studying the intervention(s) and how they were addressed, including, but not limited to, formal ethics review and potential conflict(s) of interest	11
	#13a	Initial steps of the intervention(s) and their evolution over time (e.g., time-line diagram, flow chart, or table), including modifications made to the intervention during the project	N/A
	#13b	Details of the process measures and outcome	8-11

	#13c	Contextual elements that interacted with the intervention(s)	7-11
	#13d	Observed associations between outcomes, interventions, and relevant contextual elements	11-17
	#13e	Unintended consequences such as unexpected benefits, problems, failures, or costs associated with the intervention(s).	18-20
	#13f	Details about missing data	8-11
Summary	#14a	Key findings, including relevance to the rationale and specific aims	21
	#14b	Particular strengths of the project	18-21
Interpretation	#15a	Nature of the association between the intervention(s) and the outcomes	18-21
	#15b	Comparison of results with findings from other publications	18-21
	#15c	Impact of the project on people and systems	18-21
	#15d	Reasons for any differences between observed and anticipated outcomes, including the influence of context	18-21
	#15e	Costs and strategic trade-offs, including opportunity costs	18-21
Limitations	#16a	Limits to the generalizability of the work	21-22
	#16b	Factors that might have limited internal validity such as confounding, bias, or imprecision in the design, methods, measurement, or analysis	21-22
	#16c	Efforts made to minimize and adjust for limitations	21-22
Conclusion	#17a	Usefulness of the work	22
	#17b	Sustainability	22
	#17c	Potential for spread to other contexts	21-22
	#17d	Implications for practice and for further study in the field	18-22
	#17e	Suggested next steps	18-22
Funding	#18	Sources of funding that supported this work. Role, if any, of the funding organization in the design, implementation,	22 & 23

interpretation, and reporting

BMJ Open

Barriers and facilitators to adopting high value practices and de-adopting low value practices in the Intensive Care Unit: A multi method study

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ABSTRACT

Objective: To compare and contrast illustrative examples of the adoption of high value practices and the de-adoption of low value practices.

Design: 1) Retrospective, population-based audit of low molecular weight heparin (LMWH) for venous thromboembolism (VTE) prophylaxis (high value practice) and albumin for fluid resuscitation (low value practice) and 2) Cross-sectional survey of healthcare providers.

Setting: Data were collected from nine adult medical-surgical ICUs in two large Canadian cities. Patients are managed in these ICUs by a group of multi-professional and multi-disciplinary healthcare providers.

Participants: Participants included 6946 ICU admissions and 309 healthcare providers from the same ICUs.

Main Outcome Measures: 1) The use of LMWH for VTE prophylaxis (percent ICU days) and albumin for fluid resuscitation (percent of patients); and 2) provider knowledge of evidence underpinning these practices, and barriers and facilitators to adopt and de-adopt these practices.

Results: LMWH was administered on 38.7% of ICU days, and 20.0% of patients received albumin.

Most participants had knowledge of evidence underpinning VTE prophylaxis and fluid resuscitation (59.1% and 84.2%, respectively). Providers perceived these practices to be followed. The most commonly reported barrier to adoption was insufficient knowledge/understanding (32.8%), and to de-adoption was clinical leader preferences (33.2%). On-site education was the most commonly identified facilitator for adoption and de-adoption (67.8% and 68.6%, respectively).

Conclusions: Despite knowledge of and self-reported adherence to best practices, the audit demonstrated opportunity to improve. Provider-reported barriers and facilitators to adoption and de-adoption are broadly similar.

KEY WORDS: Intensive Care; Appropriateness, Under-use and Over-use; Healthcare System; Quality Improvement

STRENGTHS & LIMITATIONS

- A strength of this study is the use of mixed-methods to comprehensively compare adoption of high value practices and de-adoption of low value practices in the ICU.
- Another strength is the use of population-based data to capture current clinical practices.
- The survey used to assess barriers and facilitators of the two illustrative practices was derived from a validated survey instrument. It was simple and designed to garner a representative perspective from all provider professions and therefore captured key concepts, but not granular data.

- Our study provides several insights into similarities and differences between adoption of high value practices and de-adoption of low value practices.

INTRODUCTION

Optimizing the quality of care[1] is of particular importance in the intensive care unit (ICU) due to the acuity of patient illness and substantial resources required to care for these patients. However, practice change (adopting high value practices or de-adopting low value practices) is slow with some evidence suggesting it can take well over a decade.[2] To minimize the latency for change, it is important to find ways to improve the implementation of evidence-based practices.

A growing body of evidence has evaluated barriers and facilitators for adopting high value practices (effective at improving outcomes).[3-6] Substantially less is known about the barriers and facilitators for de-adopting low value practices (ineffective at improving outcomes or harmful), and how they compare to those for adopting high value practices.[7,8] De-adoption, also known by several other terms such as disinvestment and de-implementation,[7] is the discontinuation of a practice that has been previously adopted.[9] Some have suggested that the adoption of high value practices and de-adoption of low value practices involves similar processes and common facilitators and barriers;[10,11] however, others suggest that the two are clearly distinct.[8,12] There has been limited comparative evaluation of adoption and de-adoption and this is an important knowledge gap given the growing number of initiatives aimed at de-adopting low value practices.[13-16]

The objective of this study was to describe illustrative example practices of the adoption of a high value practice (use of low molecular weight heparin [LMWH] instead of unfractionated heparin [UFH] for venous thromboembolism prophylaxis [VTE] and the de-adoption of a low value practice (albumin for fluid resuscitation) in the ICU. The results of this study prompted a subsequent implementation study to improve these two practices. The audit data identified important opportunities to improve clinical care, and the perceived barriers and facilitators identified in the survey were used to inform the development of interventions.

METHODS

Study design

This multi-method observational study included: 1) a retrospective cohort study of patients admitted to ICUs to describe current VTE prophylaxis and fluid resuscitation practices, and 2) a cross-sectional survey of ICU healthcare providers to examine: knowledge of evidence underpinning these two practices, and perceived barriers and facilitators to adopt LMWH for VTE prophylaxis and de-adopt albumin for fluid resuscitation.

Setting

All data were collected from nine adult medical-surgical ICUs in the two largest cities in a Canadian province (population of 4.1 million). A single health services provider is responsible for the provision of all hospital-based care in the province and uses a single formulary across all ICUs (clinical practices may differ between cities and sites).

ICU patients are managed by a multi-disciplinary and multi-professional group of healthcare providers, including (but not limited to): physicians, medical trainees (clinical fellows and residents), nurse practitioners (NPs with prescribing privileges), pharmacists, and nurses (managers, educators, bedside).

Audit of current practices

Participants

We included patients admitted to nine adult medical-surgical ICUs between January 1, 2014 and December 31, 2014. For analyses, patients were grouped into two cohorts.

1) The adoption cohort consisted of patients without a contraindication for pharmacological VTE prophylaxis where according to international and local guidelines LMWH should be prescribed.[17-21] Contraindications to pharmacological prophylaxis included a diagnosis potentially associated with a high risk of bleeding (Supplemental Content 1), daily assessed platelet count <50 x10^9/L, INR ≥2, PTT ≥55 seconds, or receipt of therapeutic anti-coagulation.

2) The de-adoption cohort consisted of patients without an indication for use of albumin for fluid resuscitation and where according to the current evidence-base albumin should not be used for fluid resuscitation.[22-25] Potential indications for albumin included documented liver disease (cirrhosis or hepatic failure), or receipt of plasma exchange.[26-29] The two study cohorts were drawn from the same patient population and patients satisfying both sets of clinical indications were included in both cohorts.

Data source

All nine ICUs employ a shared integrated, prospective, clinical information system that captures and delivers multimodal patient data (demographic, clinical, outcome) in real time to the bedside (eCritical MetaVision, iMDsoft, MetaVision), and is also a repository and clinical analytics system that stores these data (eCritical TRACER) to support quality improvement and clinical research. eCritical TRACER was used to extract all data.

Variables

Patient and ICU demographic variables included age, sex, comorbidities, admission type, disease severity (APACHE II score), ICU and hospital length of stay, ICU and hospital mortality. Data abstracted included: 1) type of VTE prophylaxis (mechanical included antiembolic stockings and sequential compression devices, and pharmacological included unfractionated heparin [UFH] and LMWH), 2) ICU day that VTE prophylaxis was administered, 3) if the patient received albumin, 4) quantity (units) of albumin, and 5) ICU day that albumin was administered. An ICU day was defined as any portion of a day between 07:00 and 06:59, recognizing that follow-up time on admission day and discharge day may be less than 24 hours.

Data analysis

Descriptive statistics (means with standard deviations [SD], medians with interquartile ranges [IQR], frequencies with proportions) were used to describe the two cohorts. The proportion of admissions and ICU days with LMWH, UFH, and mechanical VTE prophylaxis by ICU and ICU day; and with any albumin administration by ICU and

patient were calculated to describe current clinical practices. The unit of analysis for our outcome for the adoption cohort (LMWH use) was patient days because VTE prophylaxis is a routine clinical practice that should be performed on a daily basis. Conversely, the unit of analysis for our outcome for the de-adoption cohort (albumin use) was per patient because fluid resuscitation is a sporadic event that is not part of routine daily patient care.

To examine potential associations between patient demographic and sites, and the use of the high value practice (LMWH) a multivariable generalized estimating equations (GEEs) logistic regression model with exchangeable correlation structure given daily measurements (clustering by patient) was used. To examine potential associations between demographic and site-level factors, and the use of the low value practice (albumin) a multivariable logistic regression model given a single measurement per patient was used.

Barriers and facilitators to adopting LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation

Survey development

The survey was modeled after previous work on adoption of LMWH for VTE prophylaxis,[30] and refined to include questions regarding fluid resuscitation. Because research around barriers and facilitators of de-adopting low value practices is in its infancy[31] the evidence of barriers and facilitators for adopting high value practices was employed.

The survey was divided into four sections: participant demographic information, knowledge of the current evidence underpinning the best practices, and perceptions of barriers and facilitators to the use of the two illustrative examples of best practices (Supplemental Content 2).

The survey was pilot tested in two phases: Phase 1) Seven providers completed the survey and identified unnecessary, missing, or poorly worded items. The survey was modified and pilot tested with 12 additional ICU providers (1 attending physician, 2 residents, 1 clinical fellow, 1 nurse practitioner, 1 nurse manager/charge nurse, 1 nurse educator, 2 bedside nurses, and 3 pharmacists). Phase 2) Providers completed the survey twice (7-10 days apart) and an additional brief questionnaire to rate the clinical sensibility of the survey. Test-retest reliability of the survey demonstrated a mean intraclass correlation coefficient (ICC) of 0.66 (SD 0.47) for continuous responses and a mean proportion of agreement of 0.86 (SD 0.10) for categorical responses. The low ICC for continuous responses is due to low variability in responses for questions relating to knowledge of best practices. The participants agreed that the survey had face validity (100%), content validity (92%), clarity (92%), utility (100%), discriminability (75%), and minimal redundancy (100%).

Participants

Healthcare providers (as described in Setting) that cared for patients in the nine ICUs were invited by email to participate in the study. Invitations to participate were sent to

healthcare providers by the principal investigators or by a local clinical leader and included a link to the electronic survey (Fluid Survey) or were provided a paper copy if requested. Weekly reminders were sent for three weeks. Providers that responded to the survey were offered entry into a draw for one of three $20 coffee gift cards.

Data Analysis

We used descriptive statistics to describe demographic features of participants, knowledge of best practices, perceived barriers to adopting high value practices and de-adopting low value practices, perceived facilitators to encourage adopting high value practices and de-adopting low value practices. Barriers and facilitators to the use of best practices were described overall, and by professional group. Professions were categorized into three groups for analysis: 1) Physicians/NPs (those who prescribe), 2) Nurses (those who administer), and 3) Pharmacists (those who advise prescribers). Chi-squared tests were used to test for statistical significance between groups.

Patient and public involvement

Patient and family representatives were members of a committee that identified and prioritized research questions for improving the care of critically ill patients.[32] LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation were two of the research questions identified by this committee. Patients were not involved in the design, the recruitment and conduct of this study. The results of this study have been disseminated to patient and family advisors through oral presentations.

Ethical considerations

This study was approved by the University of Calgary Conjoint Health Research Ethics Board (REB14-0992 and REB15-2147) and the University of Alberta Research Ethics Board (Pro00056709 and Pro00060650).

RESULTS

Audit of current practices

There were 6,946 ICU admissions during the study period, from 6,299 unique patients. Patient characteristics are presented in Supplemental Content 3.

The adoption cohort consisted of 4,931 admissions (71.0% of all admissions) without a contraindication to pharmacological VTE prophylaxis, and the de-adoption cohort consisted of 6,467 admissions (93.1%) without a potential indication for albumin (Supplemental Content 4).

During the ICU stay LMWH was given on 38.7% of ICU days, UFH on 45.3% of ICU days and mechanical prophylaxis (exclusive of pharmacological prophylaxis) on 7.7% of ICU days. The type of VTE prophylaxis administered varied throughout patients' ICU stay; administration of mechanical devices and UFH decreased over the course of the ICU stay while administration of LMWH increased (Supplemental Content 5).

6,804 units of albumin were administered to 20.0% of the 6,467 admissions without documented liver disease or receipt of plasma exchange. Among those receiving at least 1 unit of albumin, the median number of units per patient was 3 (IQR=1.0-6.0). Albumin was administered on 6.5% of ICU days.

When controlling for demographic and site-level factors, the odds of receiving LMWH for VTE prophylaxis and not receiving albumin for fluid resuscitation were significantly lower for those patients with higher severity of illness (APACHE II score). The odds of receiving LMWH for VTE prophylaxis were significantly higher for patients with non-surgical admissions compared to those with elective surgical admissions (odds ratio = 1.34 (95% confidence interval 1.08-1.66); Table 1). There were significant differences in the odds of using LMWH for VTE prophylaxis, and not using albumin for fluid resuscitation across ICUs (Supplemental Content 6), and when controlling for patient-level factors some of these differences persisted especially with regards to the use of LMWH for VTE prophylaxis (Table 1).

Table 1. Association between patient demographic and sites, and the use of LMWH for VTE prophylaxis and not using albumin for fluid resuscitation

	Appropriate VTE prophylaxis OR (95% CI)*	**Appropriate fluid resuscitation OR (95% CI)****
Age	NS†	0.999 (0.999-1.00)
Female	NS†	NS†
Any comorbidity	NS†	NS†
Admission type		
Elective surgery	1.00 (reference group)	1.00 (reference group)
Emergent surgery	1.19 (0.92-1.53)	0.92 (0.88-0.95)
No surgery	1.34 (1.08-1.66)	1.02 (0.98-1.05)
APACHE II Score (ICU admission)	0.958 (0.951-0.965)	0.989 (0.988-0.990)
Site		
C1	1.00 (reference group)	1.00 (reference group)

C2	1.32 (1.07-1.64)	0.96 (0.92-1.00)
C3	1.13 (0.89-1.46)	0.98 (0.94-1.03)
C4	1.48 (1.15-1.90)	0.98 (0.93-1.02)
E1	2.12 (1.66-2.73)	0.90 (0.86-0.95)
E2	0.86 (0.71-1.05)	0.90 (0.87-0.92)
E3	7.26 (5.46-9.65)	0.92 (0.87-0.97)
E4	0.76 (0.63-0.92)	0.88 (0.85-0.91)
E5	1.61 (1.23-2.10)	0.75 (0.72-0.79)

Footnote: all "C" sites indicate ICU in Calgary and all "E" sites indicate ICU in Edmonton

*multivariable generalized estimating equations (GEEs) logistic regression model with exchangeable correlation structure given daily measurements (clustering by patient); "appropriate" considered *use of LMWH*

**standard multivariable logistic regression model given single measurement per patient; "appropriate" considered *not using albumin*

†NS = non-significant, removed from model

Barriers and facilitators to adopting LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation

Participants

83.8% (259 of 309) of participants responded; physicians/NPs (48.3%), nurses (42.5%), and pharmacists (9.3%). Participants worked in healthcare for a median of 13 years (IQR=7.1-20.0) and in critical care for a median of 8 years (IQR=3.0-15.0; Supplemental Content 7).

Knowledge of evidence

Most participants reported that LMWH was most effective at preventing deep vein thrombosis and pulmonary embolism; and that crystalloids were most effective for fluid resuscitation (Table 2). Perceptions regarding the effectiveness of VTE prophylaxis varied by professional group, as did perceptions regarding the risks of harm (Table 2). Perceptions regarding effectiveness of albumin for fluid resuscitation and risks of

harm associated with each form of fluid resuscitation did not vary by professional group but perceptions regarding the risk of fluid overload did (Table 2).

It was perceived that both best practices were being followed in the ICUs where the participants practiced (Table 2).

Table 2. Knowledge of best practices for VTE prophylaxis and fluid resuscitation

	% (N)			
Survey question	**Overall N=259**	**Physicians/NPs 48.3% (N= 125)**	**Nurses 42.5% (N= 110)**	**Pharmacists 9.3% (N= 24)**
What form(s) of prophylaxis is/are most effective at preventing deep vein thrombosis?*				
LMWH only	59.1 (153)	63.2 (79)	51.8 (57)	70.8 (17)
UFH only	4.3 (11)	2.4 (3)	7.3 (8)	0.0 (0)
LMWH & UFH	16.2 (42)	24.0 (30)	5.5 (6)	25.0 (6)
Mechanical only	1.9 (5)	0.0 (0)	4.6 (5)	0.0 (0)
(LMWH or UFH) and Mechanical	15.1 (39)	8.0 (10)	25.5 (28)	4.2 (1)
Unsure only	3.5 (9)	2.4 (3)	5.5 (6)	0.0 (0)
What form(s) of prophylaxis is/are most effective at preventing pulmonary embolism? *				
LMWH only	56.8 (147)	72.0 (90)	33.6 (37)	83.3 (20)
UFH only	18.2 (47)	1.6 (2)	40.9 (45)	0.0 (0)
LMWH & UFH	12.7 (33)	20.8 (26)	3.6 (4)	12.5 (3)
Mechanical only	0.4 (1)	0.0 (0)	0.9 (1)	0.0 (0)
(LMWH or UFH) & Mechanical	8.5 (22)	3.2 (4)	15.5 (17)	4.2 (1)
Unsure only	3.5 (9)	2.4 (3)	5.5 (6)	0.0 (0)
Which form(s) of prophylaxis is/are most cost effective?*				
LMWH only	51.0 (132)	70.4 (88)	22.7 (25)	79.2 (19)
UFH only	15.4 (40)	12.8 (16)	20.0 (22)	8.3 (2)
LMWH & UFH	4.3 (11)	5.6 (7)	0.9 (1)	12.5 (3)
Mechanical only	10.0 (26)	4.8 (6)	18.2 (20)	0.0 (0)
(LMWH or UFH) & Mechanical	2.7 (7)	0.0 (0)	6.4 (7)	0.0 (0)
Unsure only	16.6 (43)	6.4 (8)	31.8 (35)	0.0 (0)
Which form(s) of pharmacological prophylaxis has/have the lowest risk of bleeding?†				
LMWH only	57.5 (149)	47.2 (59)	69.1 (76)	58.3 (14)
UFH only	24.7 (64)	32.8 (41)	18.2 (20)	12.5 (3)
LMWH & UFH	5.0 (13)	6.4 (8)	0.0 (0)	20.8 (5)
Unsure only	12.7 (33)	13.6 (17)	12.7 (14)	8.3 (2)
Which form(s) of pharmacological prophylaxis has/have the lowest risk of heparin induced thrombocytopenia?*				

LMWH only	86.1 (223)	94.4 (118)	74.6 (82)	95.8 (23)
UFH only	6.6 (17)	3.2 (4)	11.8 (13)	0.0 (0)
LMWH & UFH	0.4 (1)	0.0 (0)	0.0 (0)	4.2 (1)
Unsure only	7.0 (18)	2.4 (3)	13.6 (15)	0.0 (0)
To what extent do you think best practices are followed for preventing DVT/PE in your ICU? 0=never and 7=always, Median (IQR)				
	6 (5-6)	6 (5-6)	6 (6-7)	6 (5-6)
Survey question	**Overall N=259**	**Physicians/NPs 48.3% (N= 125)**	**Nurses 42.5% (N= 110)**	**Pharmacists 9.3% (N= 24)**
What form(s) of IV fluids is/are most effective for fluid resuscitation?‡				
Albumin only	3.5 (9)	2.4 (3)	5.5 (6)	0.0 (0)
Crystalloids only	84.2 (218)	83.2 (104)	82.7 (91)	95.8 (23)
Albumin & Crystalloids	8.5 (22)	9.6 (12)	9.1 (10)	0.0 (0)
Unsure only	3.9 (10)	4.8 (6)	2.7 (3)	4.2 (1)
Which form(s) of IV resuscitation fluids are most cost effective? ‡				
Albumin only	0.4 (1)	0.0 (0)	0.9 (1)	0.0 (0)
Crystalloids only	94.6 (245)	94.4 (118)	95.5 (105)	91.7 (22)
Albumin & Crystalloids	0.4 (1)	0.8 (1)	0.0 (0)	0.0 (0)
Unsure only	4.6 (12)	4.8 (6)	3.6 (4)	8.3 (2)
Which form(s) of IV resuscitation fluids has the lowest risk of fluid overload? *				
Albumin only	47.1 (122)	32.8 (41)	69.1 (76)	20.8 (5)
Crystalloids only	29.7 (77)	36.8 (46)	23.6 (26)	20.8 (5)
Albumin & Crystalloids	1.9 (5)	3.2 (4)	0.0 (0)	4.2 (1)
Unsure only	21.2 (55)	27.2 (34)	7.3 (8)	54.2 (13)
Which form(s) of IV resuscitation fluids has the lowest risk of infectious disease? ‡				
Albumin only	2.7 (7)	1.6 (2)	4.6 (5)	0.0 (0)
Crystalloids only	86.5 (224)	87.2 (109)	87.3 (96)	79.2 (19)
Albumin & Crystalloids	0.8 (2)	0.8 (1)	0.9 (1)	0.0 (0)
Unsure only	10.0 (26)	10.4 (13)	7.3 (8)	20.8 (5)

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To what extent do you think best practices are followed for prescribing fluid boluses in your ICU? 0=never and 7=always; Median (IQR)				
	6 (5-6)	5 (5-6)	6 (5-6)	5 (5-6)

[1]The order of the survey items are as presented in this table.

[2]Evidence suggests the efficacy of LMWH for deep vein thrombosis is similar to or better than UFH.[18,19,33,34] Evidence suggests that LMWH is more efficacious than UFH for preventing pulmonary embolism, has a lower incidence of heparin induced thrombocytopenia, and a similar or lower risk of bleeding.[18,19,33,34]

[3]Evidence suggests that LMWH is more cost effective than UFH.[18]

[4]Evidence suggests that albumin and crystalloids are similarly effective for fluid resuscitation.[21,24,26] Evidence suggests that albumin has a higher risk of infectious disease transmission than crystalloids and is less cost-effective than crystalloids.

Abbreviations: **IQR** = interquartile range (p25 - p75), **LMWH** = low molecular weight heparin, **N** = number, **NP** = nurse practitioner, **UFH** = unfractionated heparin, ***** = responses varied by professional group (p<0.001), **†**= responses varied by professional group (p=0.01), **‡**= responses did not vary by professional group (p>0.05)

Barriers to adopting LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation

Barriers to adoption and de-adoption were reported by 65.2% and 64.9% of respondents, respectively. The most commonly reported perceived barriers to adopting LMWH for VTE prophylaxis were insufficient knowledge or understanding, ICU culture, and no clinical guidelines (Figure 1). The most commonly reported barriers to de-adopting albumin for fluid resuscitation were a strong clinical preference of the local clinical leaders in the ICUs, ICU culture, and insufficient knowledge or understanding (Figure 1). Reported barriers differed between professional groups for both adoption (Figure 2a) and de-adoption (Figure 2b).

Facilitators to adopting LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation

On site education and pre-set orders were perceived to be the most commonly reported facilitator of both adoption and de-adoption (Figure 3). Verbal reminders from pharmacists to physicians was commonly reported as a perceived facilitator for adopting LWMH for VTE prophylaxis. A local leader championing the practice was commonly reported as a perceived facilitator for de-adopting albumin for fluid resuscitation (Figure 3). There was no variability by professional group.

DISCUSSION

The present study identified opportunities to improve the use of best practices for VTE prophylaxis (adopting the high value practice of LMWH) and fluid resuscitation (de-adopting the low value practice of albumin). Our audit data demonstrated that current practice does not reflect providers' understanding of the evidence for these practices. The use of the best practice for these two illustrative examples were less likely for patients with greater severity of illness and varied across institutions. The perceived barriers and facilitators to adoption and de-adoption were broadly similar.

Are de-adoption and adoption just the flip-side of the same coin? There is substantial literature describing the adoption of high value practices, but much less is known about de-adoption of low value practices.[7] Science can inform clinical practice through discovery resulting in adoption of a new practice, replacement resulting in a practice update, and reversal resulting in de-adoption of an existing practice. It is only recently that the last concept, de-adopting low value practices, has been debated in journals and by professional societies.[13,14,16] The practical implication is that there is limited evidence to inform whether the barriers and facilitators for adoption and de-adoption are similar or sufficiently distinct to warrant different approaches.[8,10-12] Our study adds to the limited evidence base by suggesting that culture or organizational factors, provider characteristics, and patient characteristics are perceived to be important barriers and facilitators that may play broadly similar roles in adoption and de-adoption.[10,11]

Knowledge translation (KT) interventions are strategies to improve the synthesis, dissemination, exchange, and application of evidence to improve health.[4] KT interventions tailored to the specific barriers and facilitators of an innovation and the local context are more likely to effect change.[4,5] Our study provides insight into the perceived barriers and facilitators of adopting high value practices (LMWH for VTE prophylaxis) and de-adopting low value practices (albumin for fluid resuscitation) within ICUs, which should be taken into consideration when designing KT interventions. Interestingly, despite knowledge of the evidence underlying the illustrative example practices, providers perceived insufficient knowledge or understanding to be a barrier and perceived education to be a facilitator to both adopting high value practices and de-adopting low value practices. These barriers and facilitators are consistent with a systematic review that suggests the most effective KT interventions in the ICU employ a combination of education and protocols.[35] While consistent with previous KT studies, this finding is paradoxical. It is possible that while knowledgeable, providers' confidence in applying their knowledge clinically was low and they believed education to be the intervention needed to improve their confidence in applying their knowledge. Furthermore, confidence in applying new evidence in clinical practice may be particularly challenging in the care of severely ill patients. This hypothesis is supported by two of our findings: 1) the use of LMWH for VTE prophylaxis and not using albumin for fluid resuscitation was inversely associated with severity of patient illness and 2) the use of LMWH and not using albumin increased as the patient became more stable (over ICU stay). Potential hypotheses to explain these observations include that clinicians may employ conservative decision-making (use

more familiar practices) or unintendedly neglect to use best practices when caring for sicker patients, but this need further exploration. The implications are that KT interventions should consider clinician heuristics that are likely to be influenced by the nature and severity of patient illness.

Our study suggests that factors other than knowledge may contribute to the successful adoption of high value practices and de-adoption of low value practices, which includes culture, providers, and the innovation. These factors have previously been identified within the context of the ICU. [36-42] ICU culture and local clinical leader preferences were among the most commonly endorsed barriers to adopting high value practices and de-adopting low value practices in this study and in our study. This is highlighted by the variation in the use of LMWH between ICUs, even when patient level factors were taken into consideration. Interestingly, this finding was less pronounced for de-adoption, which has been previously reported.[8] Culture, also referred to as organizational context, is a frequently cited barrier to evidence-based medicine and can have a profound effect on clinical practice.[6,43] However, few studies have systematically evaluated the effect of culture on adopting high value practices and de-adopting low value practices, and implementation studies infrequently account for the effect of culture on their practice change interventions.[44] Similarly, the professional role of the provider is not often contextualized but may be important (e.g., should pharmacists and nurses be targeted in KT interventions designed to change the prescribing patterns of physicians and if so how?).[45] This may be especially

relevant as healthcare delivery becomes increasingly multi-professional and team-based as illustrated in our setting (ICU).

The characteristics of innovations themselves may influence change in clinical practice. Evidence suggests that if the innovation being adopted is congruent with clinical practice beliefs it can facilitate adoption.[6] Furthermore, the quality, quantity, and stability of available evidence to support the adoption or de-adoption of an innovation is likely important.[46] Although most providers in our study were aware of the evidence to support the adoption of LMWH for VTE prophylaxis and de-adoption of albumin for fluid resuscitation, they may not have perceived the evidence to be sufficient to warrant practice change. A growing awareness of challenges with reproducing scientific evidence and clinician experience with practice reversals[42] may result in more conservative provider behavior and slower practice change in response to new evidence. The suboptimal prescribing practices observed in our study likely represent a combination of all these factors.

One limitation of this study is that the survey used was imperfect. The results of the self-reported survey reflect perceived modifiers of practice among providers rather than factors shown to influence practice patterns as identified in observational studies.[47] The survey was purposefully designed to be simple and accessible to garner a representative perspective from all provider professions and therefore captured key concepts, but not granular data. Nevertheless, the survey has been successfully used for a similar purpose by others;[30] was reliable and reported to have

good clinical sensibility. Alternative methodologies such as qualitative analyses of semi-structured interviews may have allowed for more in depth exploration of barriers and facilitators to adopting LMWH and de-adopting albumin. Finally, while this study was a provincial and multi-site it was constrained to ICUs, which should be taken into consideration when interpreting our findings beyond this setting.

In conclusion, our study provides several insights into similarities and differences between adoption of high value practices and de-adoption of low value practices. Both adoption and de-adoption of the illustrative example practices did not reflect healthcare providers' knowledge of the evidence. The use of best practices for both illustrative examples practices were less likely for patients with greater severity of illness and varied across institutions. We found that perceived barriers and facilitators are more similar than different between adoption and de-adoption, which suggests existing behavior change frameworks for adopting high value practices may also be applicable for de-adopting low value practices.

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DISCLOSURE OF CONFLICT OF INTERESTS

The authors declare that they have no competing interests.

DATA SHARING STATEMENT

Data will be available if accepted.

AUTHORS' CONTRIBUTIONS

Dr. Sauro contributed to the design and conceptualization of the study; analysis and interpretation of the data, drafting and revising the manuscript and gave approval of the final version of the manuscript. No conflicts of interest to declare.

Dr. Bagshaw contributed to the design and conceptualization of the study, interpretation of the data, providing feedback on the manuscript, and gave approval of the final version of the manuscript. No conflicts of interest to declare.

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Figure 1. Barriers to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation)

Abbreviations: ICU: intensive care unit

Figure 2a. Barriers to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) by professional group.

Figure 2b. Barriers to the de-adoption of low value practices (albumin for fluid resuscitation) by professional group

Abbreviations: **ICU**=intensive care unit, **NP**=nurse practitioner

Figure 3. Facilitators to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation)

Abbreviation: **MD=**medical doctor, **QI=**quality improvement

Figure 1. Barriers to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation)

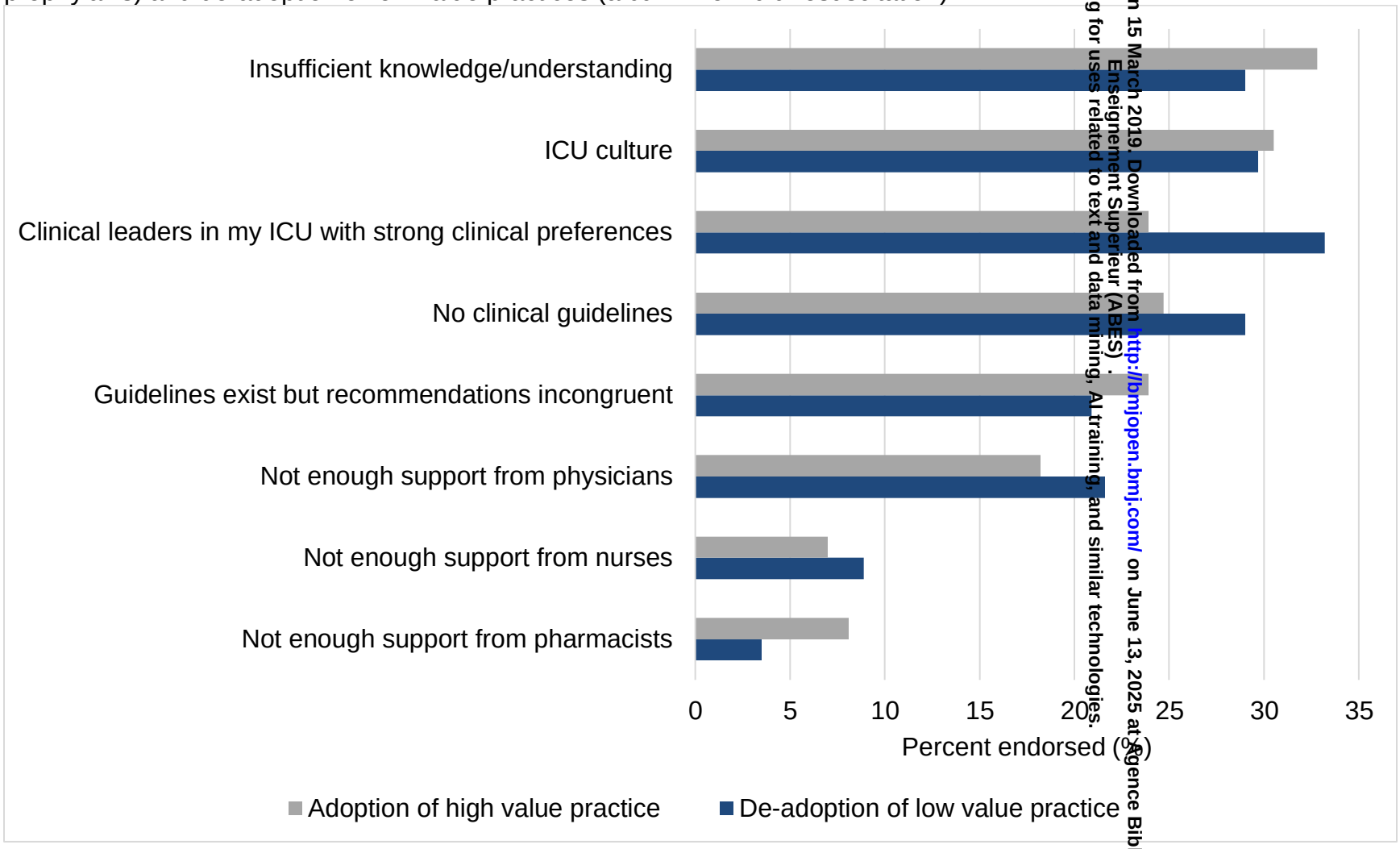
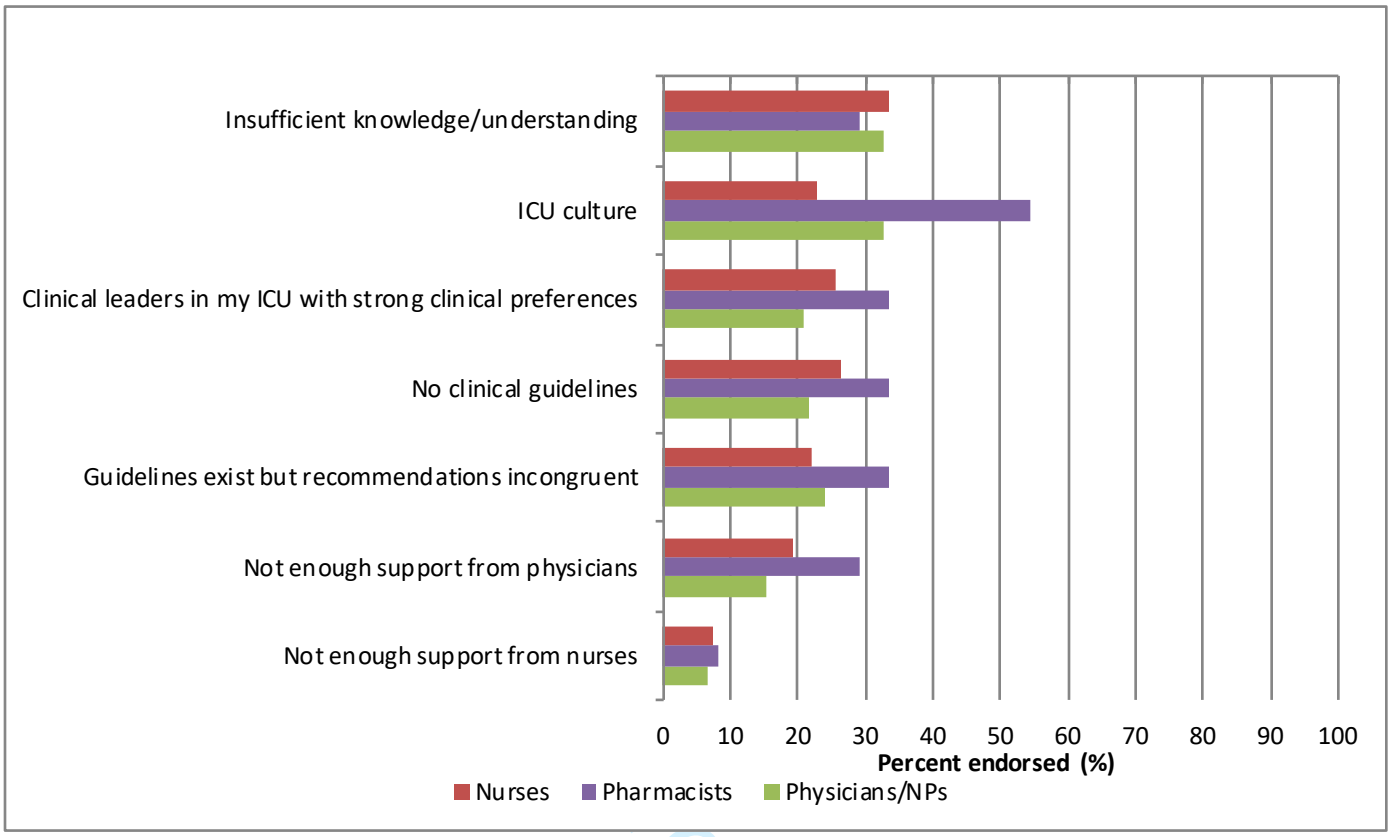
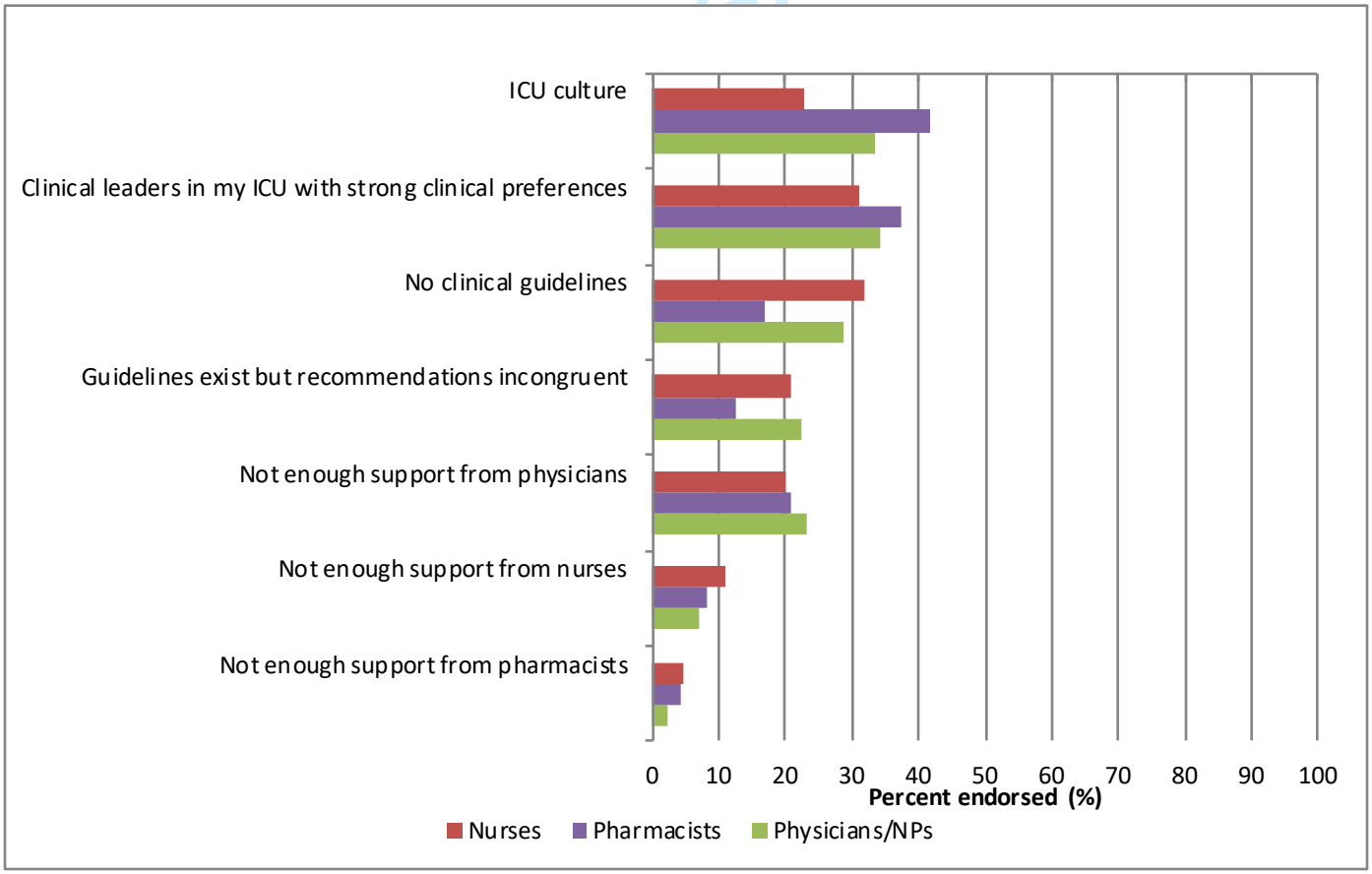


Figure 2. Barriers to adopting high value practices and de-adopting low value practices by profession

2.a) Barriers to adopting high value practices (LMWH for VTE prophylaxis) by professional group

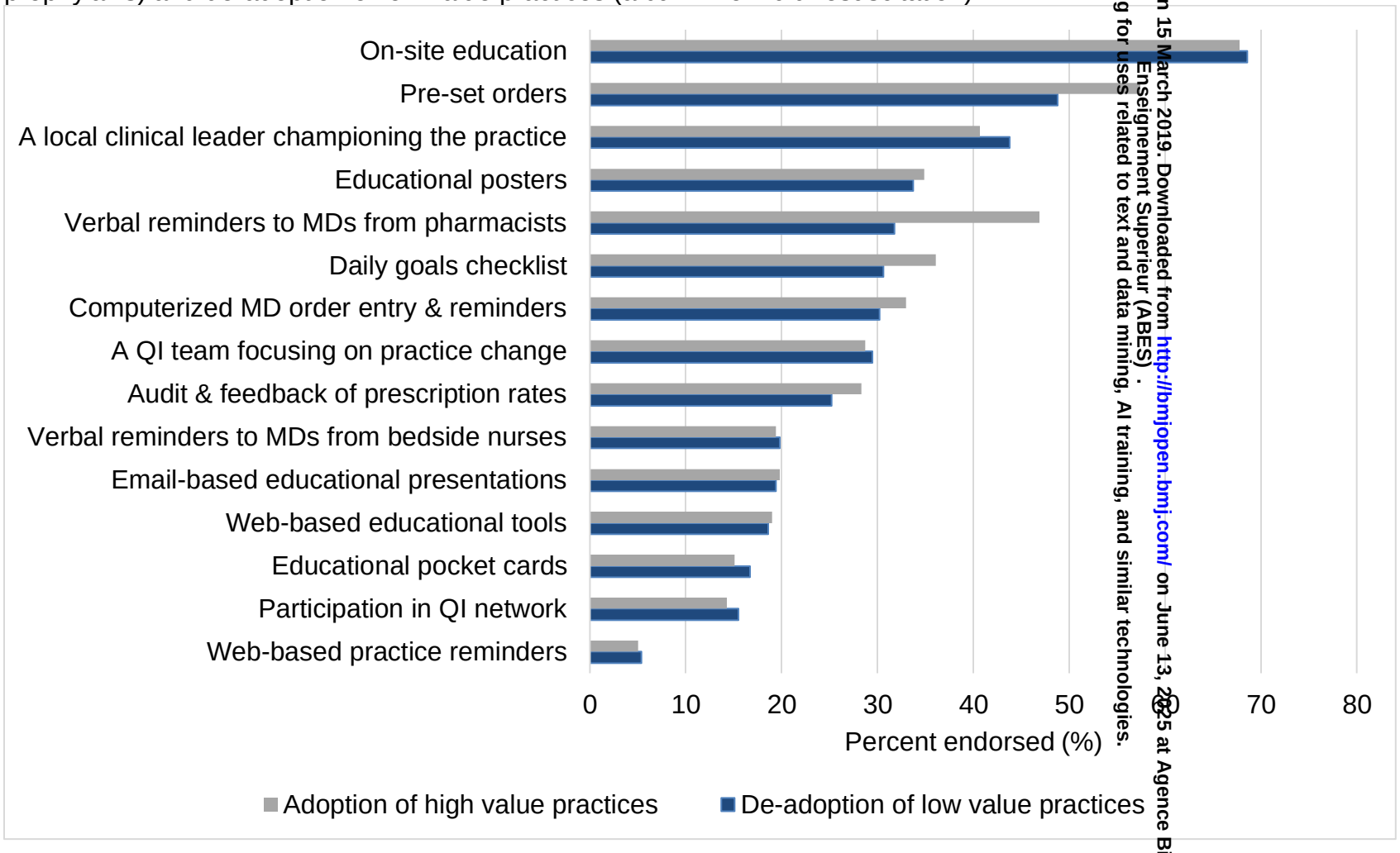


2.b) Barriers to de-adopting low value practices (albumin for fluid resuscitation) by professional group



Abbreviations: ICU=intensive care unit; NP=nurse practitioner; LMWH=low molecular weight heparin; VTE=venous thromboembolism

Figure 3. Facilitators to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation)



Abbreviation: **MD=**medical doctor, **QI**=quality improvement

Supplemental Content 1. List of diagnoses with a potential contraindication to receive pharmacological venous thromboembolism prophylaxis or indication for therapeutic anticoagulation*

Arteriovenous malformation, surgery for
Embolus, pulmonary
GI Vascular insufficiency
Grafts, removal of infected vascular
Neoplasm, neurologic
Neoplasm-cranial, surgery for (excluding transphenoidal)
Neoplasm-spinal cord surgery or other related procedures
Neurologic surgery, other
Subarachnoid hemorrhage/intracranial aneurysm
Subarachnoid hemorrhage/intracranial aneurysm, surgery for
Thrombosis, vascular (deep vein)
Transphenoidal surgery
Ulcer disease, peptic
Abdomen only trauma
Abdomen only trauma, surgery for
Abdomen/extremity trauma
Abdomen/extremity trauma, surgery for
Abdomen/face trauma
Abdomen/face trauma, surgery for
Abdomen/multiple trauma
Abdomen/multiple trauma, surgery for
Abdomen/pelvis trauma, surgery for
Abscess/infection-cranial, surgery for
Anastomosis, vascular
Aneurysm, abdominal aortic
Aneurysm, abdominal aortic; with dissection
Aneurysm, abdominal aortic; with rupture
Aneurysm, dissecting aortic
Aneurysm, thoracic aortic
Aneurysm, thoracic aortic; with dissection
Aneurysm, thoracic aortic; with rupture
Aneurysm/pseudoaneurysm, other
Aneurysms, repair of other (except ventricular)
Biopsy, brain
Bleeding, GI from esophageal varices/portal hypertension
Bleeding, GI-location unknown
Bleeding, lower GI
Bleeding, upper GI
Bleeding-lower GI, surgery for
Bleeding-other GI, surgery for
Bleeding-upper GI, surgery for

Burr hole placement
CABG alone, coronary artery bypass grafting
CVA, cerebrovascular accident/stroke
Chest/abdomen trauma
Chest/abdomen trauma, surgery for
Chest/extremity trauma
Chest/extremity trauma, surgery for
Chest/face trauma
Chest/face trauma, surgery for
Chest/multiple trauma
Chest/multiple trauma, surgery for
Chest/pelvis trauma
Chest/pelvis trauma, surgery for
Chest/spinal trauma
Chest/spinal trauma, surgery for
Chest/thorax only trauma
Chest/thorax only trauma, surgery for
Coagulopathy
Complications of prev. peripheral vasc. surgery, surgery for (i.e.ligation of bleeder, exploration and evacuation of hematoma, debridement, pseudoaneurysms, clots, fistula, etc.)
Complications of previous GI surgery; surgery for (anastomotic leak, bleeding, abscess, infection, dehiscence, etc.)
Complications of previous spinal cord surgery, surgery for
Cranioplasty and complications from previous craniotomies
Head (CNS) only trauma
Head (CNS) only trauma, surgery for
Head/abdomen trauma
Head/abdomen trauma, surgery for
Head/chest trauma
Head/chest trauma, surgery for
Head/extremity trauma
Head/extremity trauma, surgery for
Head/face trauma
Head/face trauma, surgery for
Head/multiple trauma
Head/multiple trauma, surgery for
Head/pelvis trauma
Head/pelvis trauma, surgery for
Head/spinal trauma
Head/spinal trauma, surgery for
Hematoma, epidural
Hematoma, epidural, surgery for
Hematoma, subdural
Hematoma, subdural, surgery for

Hematomas
Hemorrhage (for gastrointestinal bleeding GI-see GI system) (for trauma see Trauma)
Hemorrhage, intra/retroperitoneal
Hemorrhage, postpartum (female only)
Hemorrhage/hematoma, intracranial
Hemorrhage/hematoma-intracranial, surgery for
Hemorrhage/hemoptysis, pulmonary
Hemothorax
Pelvis/extremity trauma
Pelvis/extremity trauma, surgery for
Pelvis/face trauma
Pelvis/hip only trauma, surgery for
Pelvis/multiple trauma, surgery for
Pelvis/spinal trauma
Pericardial effusion/tamponade
Renal bleeding
Spinal cord only trauma, surgery for
Spinal cord surgery, other
Stereotactic procedure
Subarachnoid hemorrhage/arteriovenous malformation
Tamponade, pericardial

**Footnote:* The primary diagnoses were reviewed independently by two ICU physicians (HTS, DJN). The two ICU physicians provided their judgment to establish a conservative list of primary diagnoses in order to exclude patients that may have a contraindication for pharmacological VTE prophylaxis based on bleeding risk and an indication for therapeutic anticoagulation. Discrepancies were resolved by discussion.

Adopting Best Practices in DVT/PE Prophylaxis and Fluid Resuscitation in Critical Care

http://fluidsurveys.com/s/ECG_faciliatators_barriers_survey/

Informed Consent

This survey is to identify and evaluate barriers to, and facilitators of, best practices in:

1. Deep Vein Thrombosis (DVT) / Pulmonary Embolism (PE) prophylaxis for medical-surgical ICU patients, and
2. Fluid Resuscitation for medical-surgical ICU patients *without* liver disease, bacterial peritonitis, hepatorenal syndrome or therapeutic paracentesis.

This survey is not about trauma, neurosurgery or cardiac surgery patients. Survey responses will be used to develop interventions to facilitate the adoption of best practices in Alberta ICUs.

You are being asked to take part in this survey because you are a healthcare professional working in adult critical care in Alberta. Our survey can be answered in approximately **5 minutes**. There are no direct benefits and/or risks to your participation.

Survey respondents can choose to have their name entered into a draw for *$20 Starbucks gift cards* (one name will be drawn per week; non-winners will remain in the draw each week).

Your participation in this survey is voluntary and you are free to stop at any time. Your responses will be kept confidential. Your de-identified data will be stored in a password-protected database, and responses will only be presented in aggregate. The survey has peer-reviewed funding and has received ethics approval from the University of Calgary. **Your decision to complete and submit this survey will indicate your consent to participate.** Should you decide to withdraw your participation before submitting the survey, your data will be deleted.

If you have questions about this survey or your participation, please contact:
Rebecca Brundin-Mather, Research Coordinator, at brundin@ucalgary.ca.

If you have questions about your rights as a participant, you may contact the University of Calgary Conjoint Research Ethics Board at (403) 220-7990. This office is not affiliated with the study team.

Thank you in advance for taking the time to complete the survey!

Kind regards,

Tom Stelfox, MD, PhD, FRCPC
Intensive Care Physician
Scientific Director, AHS, Critical Care Strategic Clinical Network

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○ I agree to participate in this survey ○ I do **NOT** wish to participate in this survey (online-version)

Demographics

1. What is your professional group?

◯ ICU physician	◯ Nurse Clinician	◯ Pharmacist
◯ ICU resident	◯ Nurse Educator	◯ Other: _____
◯ ICU fellow	◯ Bedside Nurse	

2. Approximately how many years have you worked in:

Health care ☐ Critical care ☐

3. In which hospital(s) do you primarily work? (Select all that apply)

- ◯ Chinook Regional Hospital
- ◯ Foothills Medical Centre
- ◯ Grand Praire QE II Hospital
- ◯ Grey Nuns Hospital
- ◯ Medicine Hat Regional Hospital
- ◯ Misericordia Hospital
- ◯ Northern Lights Regional Health Centre
- ◯ Peter Lougheed Centre
- ◯ Red Deer Regional Hospital
- ◯ Rockyview General Hospital
- ◯ Royal Alexander Hospital
- ◯ South Health Campus
- ◯ Sturgeon Community Hospital
- ◯ University of Alberta Hospital

DVT/PE Prevention

We are interested in your perceptions of the different forms of prophylaxes commonly used to prevent Deep Vein Thrombosis (DVT) and Pulmonary Embolism (PE) in medical-surgical ICU patients (not trauma, neurosurgery or cardiac surgery patients). Common prophylaxes include:

- Low molecular weight heparin (**LMWH** e.g., Enoxaparin, Dalteparin, Tinzaparin)
- Unfractionated heparin (**UFH**, regular Heparin)
- **Mechanical** prophylaxis (i.e., sequential compression devices)

We appreciate that practices vary across units and providers. For each of the following questions, please select the **best response option** OR **options**, to the best of your knowledge (more than one response option can be selected).

4. Which form(s) of prophylaxis is/are most effective at preventing:

	LMWH	UFH	Mechanical	Unsure
Deep Vein Thrombosis (DVT)	☐	☐	☐	☐
Pulmonary Embolism (PE)	☐	☐	☐	☐

5. Which form(s) of prophylaxis is/are most cost-effective?

LMWH	UFH	Mechanical	Unsure
☐	☐	☐	☐

6. Which form(s) of *pharmacological* prophylaxis has/have the lowest risk of:

	LMWH	UFH	Unsure
Bleeding	☐	☐	☐
Heparin Induced Thrombocytopenia (HIT)	☐	☐	☐

7. To what extent do you think best practices for preventing DVT/PE are followed **in your ICU** (i.e., the patient receives the right prophylaxis with the right dose at the right time)?

○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ Unsure
Never			**Sometimes**			**Always**	

Intravenous Fluid Resuscitation

We are now interested in your perceptions of the different types of intravenous fluids commonly used for fluid resuscitation (i.e., fluid boluses) in the ICU for medical-surgical patients, **excluding** patients with liver disease, bacterial peritonitis, or undergoing therapeutic paracentesis as they may have different fluid needs. Common resuscitation fluids include:

- **Human Albumin** (Albumin 5% or Albumin 25%)
- **Crystalloid solutions** (e.g., normal saline, ringers lactate, and plasma-lyte)

Again, we appreciate that clinical practices vary across units and providers. For each of the following questions, please select the **best response option** OR **options**, to the best of your knowledge (more than one response option can be selected).

8. Which form(s) of IV resuscitation fluid is/are most effective for resuscitation?

Albumin ☐ Crystalloids ☐ Unsure ☐

9. Which form(s) of IV resuscitation fluid(s) is/are most cost-effective?

Albumin ☐ Crystalloids ☐ Unsure ☐

10. Which form(s) of IV resuscitation fluid(s) has/have the lowest risk of:

	Albumin	Crystalloids	Unsure
Fluid overload (peripheral / pulmonary)	☐	☐	☐
Contracting an infectious disease	☐	☐	☐

11. To what extent do you think *best practices* for prescribing fluid boluses are followed **in your ICU** (i.e., the patient receives the right fluid with the right dose at the right time)?

○	○	○	○	○	○	○	○
1	**2**	**3**	**4**	**5**	**6**	**7**	Unsure
Never			**Sometimes**			**Always**	

Barriers to Best Practices

A number of ICU or 'systems' factors have been identified as potential barriers to best practices. We are interested in what you think are barriers **in your ICU** to prescribing:

1. LMWH over UFH for DVT/PE prophylaxis
2. Crystalloid solutions over Albumin for fluid resuscitation

12. Which of the following factors are current barriers in your ICU to prescribing…

	LMWH over UFH		Crystalloids over Albumin	
	Current Barrier	Unsure	Current Barrier	Unsure
An ICU culture with an unclear or slow process for practice change	○	○	○	○
Not enough support from physicians	○	○	○	○
Not enough support from nurses	○	○	○	○
Not enough support from pharmacists	○	○	○	○
Clinical leaders in my ICU with strong clinical preferences	○	○	○	○
No clinical guidelines or orders sets in my ICU to guide the practice	○	○	○	○
Guidelines exist in my ICU, but they do not recommend LWMH over UFH / crystalloids over albumin	○	○	○	○
Insufficient knowledge/understanding the evidence base for the practice.	○	○	○	○
None of the above factors are current barriers in my ICU to prescribing….	○		○	
Please note any other factors that may be barriers to prescribing LMWH over UFH and/or crystalloids over albumin. Specify below.				

Strategies to Encourage Best Practices

A number of strategies have been identified as potential facilitators to changing clinical practice. We are interested in your perceptions of different strategies that have been used to encourage:

1. LMWH over UFH for DVT/PE prophylaxis
2. Crystalloid solutions over Albumin for fluid resuscitation

13. Which of the following strategies are currently used in your ICU to encourage…

	LMWH over UFH	Crystalloids over Albumin
1. On-site education (in-services, rounds, journal clubs, orientations)	○	○
2. Educational posters (in the unit)	○	○
3. Educational pocket cards	○	○
4. Email-based educational presentations	○	○
5. Web-based educational tools	○	○
6. Verbal reminders to physicians from pharmacists	○	○
7. Verbal reminders to physicians from bedside nurses	○	○
8. Pre-set orders	○	○
9. Computerized physician order entry & reminders	○	○
10. Web-based practice reminders	○	○
11. Daily goals checklist	○	○
12. Audit & feedback of prescription rates	○	○
13. A quality improvement team focusing on practice change	○	○
14. Participation in a quality improvement network	○	○
15. A local clinical leader championing the practice	○	○
16. Other strategy used. Please specify:	○	○
17. Other strategy used. Please specify:	○	○
NO strategies are currently being used in my ICU encourage this practice:	○	○

14. From the same list of strategies, please select the **5 best strategies** that you believe would work **in your ICU** to encourage:
    (1) LMWH over UFH for DVT/PE prophylaxis
    (2) Crystalloid solutions over Albumin for fluid resuscitation
    (Select up to **5 strategies**, regardless whether the strategy is used in your ICU or not)

Select up to 5 in each column

Strategy to change clinical practice	LMWH over UFH	Crystalloids over Albumin
1. On-site education (in-services, rounds, journal clubs, orientations)	☐	☐
2. Educational posters (in the unit)	☐	☐
3. Educational pocket cards	☐	☐
4. Email-based educational presentations	☐	☐
5. Web-based educational tools	☐	☐
6. Verbal reminders to physicians from pharmacists	☐	☐
7. Verbal reminders to physicians from bedside nurses	☐	☐
8. Pre-set orders	☐	☐
9. Computerized physician order entry & reminders	☐	☐
10. Web-based practice reminders	☐	☐
11. Daily goals checklist	☐	☐
12. Audit & feedback of prescription rates	☐	☐
13. A quality improvement team to focus on practice change	☐	☐
14. Participation in a quality improvement network	☐	☐
15. A local clinical leader to champion the practice	☐	☐
16. Other strategy. Please specify:	☐	☐
17. Other strategy. Please specify:	☐	☐

15. Finally, please provide any additional comments in the text box below.

Please select the check box(es) below to have your name entered in the Starbucks coffee card draws and/or to receive the study results.

☐ Yes, I would like my name entered in the coffee card draws.

☐ Yes, I would like to receive the results from this study.

My email address is:

N.B. E-mail addresses will be kept confidential and will not be used to contact you for any reason other than those noted above.

---End of Survey ---

Thank you for helping us improve care!

Please return completed surveys to:

Dr. Tom Stelfox
Department of Critical Care Medicine
Foothills Medical Centre

OR

Rebecca Brundin-Mather
Ward of the 21st Century
GD01 Teaching, Research, Wellness Bldg
University of Calgary, 3280 Hospital Dr NW
Calgary, AB T2N 4Z6

Supplemental Content 3. Intensive care unit patient characteristics for the study period (January 1, 2014-December 31, 2014)

Demographic variable	Population (N=6,946)	Adoption cohort 70.7% (N=4,931)	De-adoption cohort 93.1% (N=6,467)
Age, median (IQR)	60 (46-71)	61 (47-71)	61 (46-71)
Female	41.6 (2,888)	43.3 (2,134)	41.8 (2,703)
Comorbidities			
AIDS	0.6 (42)	0.7 (33)	0.5 (35)
Chronic dialysis	3.5 (240)	3.8 (186)	3.5 (225)
Chronic heart failure	6.4 (444)	7.4 (364)	6.5 (419)
Cirrhosis	5.9 (407)	6.0 (294)	0.0 (0)
Diabetes	19.7 (1,366)	21.6 (1,065)	19.9 (1,284)
Hepatic failure	3.9 (269)	4.1 (203)	0.0 (0)
Immune suppression	8.5 (589)	9.4 (463)	8.2 (532)
Leukemia or multiple myeloma	1.3 (88)	1.4 (69)	1.3 (86)
Lymphoma	1.1 (77)	1.2 (61)	1.2 (75)
Metastatic cancer	3.9 (272)	4.1 (203)	4.1 (262)
Respiratory insufficiency	12.0 (833)	14.6 (722)	12.5 (810)
Any comorbidity	44.6 (3,100)	49.3 (2,431)	40.6 (2,625)
Admitted from			
Emergency department	36.6 (2,540)	36.7 (1,808)	36.5 (2,358)
Operating / recovery room	21.9 (1,520)	18.3 (902)	22.2 (1,437)
Hospital ward	26.7 (1,858)	28.1 (1,386)	26.3 (1,702)
Other hospital	10.4 (722)	11.9 (589)	10.5 (677)
Other location	4.3 (300)	4.9 (243)	4.5 (288)
Unknown	0.1 (6)	0.1 (3)	0.1 (5)
Admission type			

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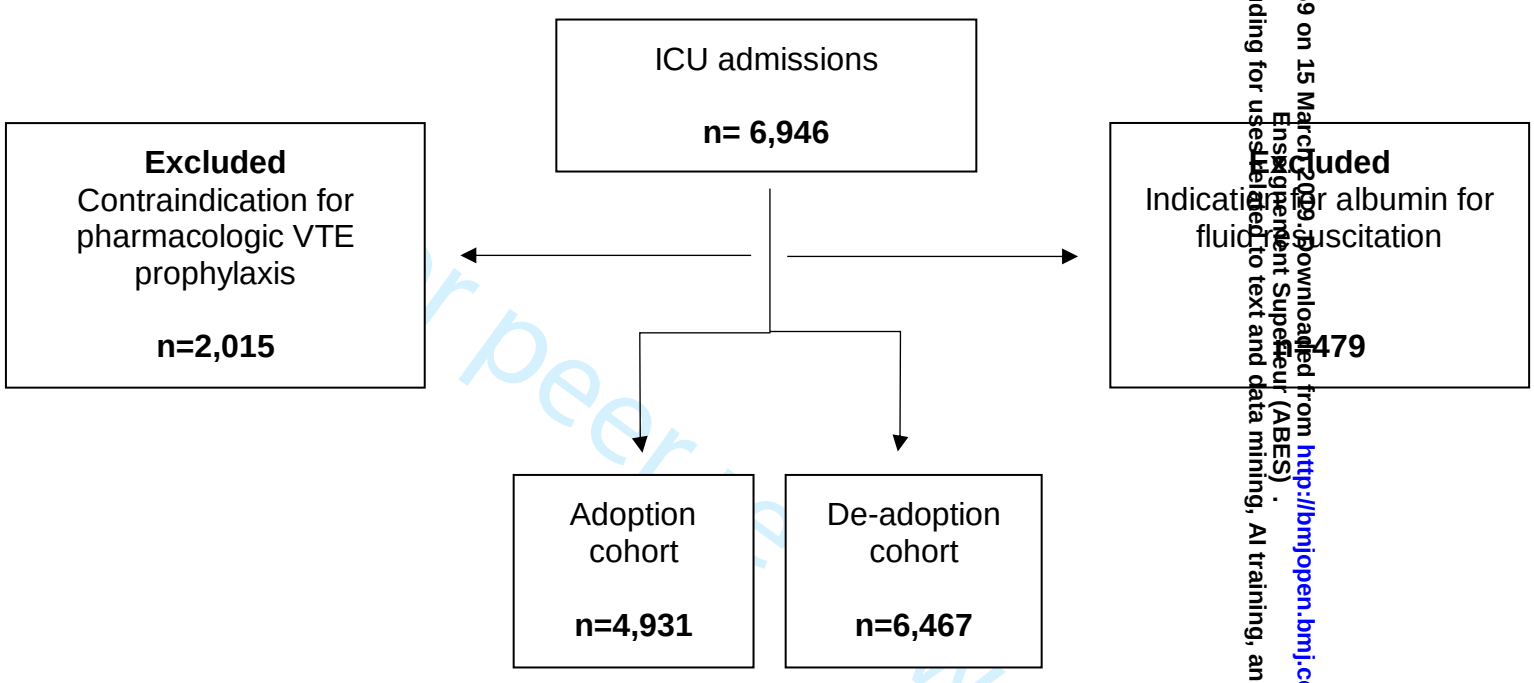
Elective surgery	9.4 (655)	8.1 (399)	9.5 (614)
Emergent surgery	16.8 (1,170)	13.8 (681)	17.3 (1,120)
No surgery	73.1 (5,078)	78.1 (3,851)	72.5 (4,690)
Unknown	0.6 (43)	0.0 (0)	0.7 (43)
Reason for ICU admission			
Medical	59.9 (4,163)	69.4 (3,420)	58.7 (3,797)
Surgical	25.8 (1,789)	24.1 (1,190)	26.2 (1,696)
Neurological	9.3 (649)	4.1 (200)	9.8 (632)
Trauma	4.3 (302)	2.5 (121)	4.6 (299)
Unknown	0.6 (43)	0.0 (0)	0.7 (43)
APACHE II Score on ICU admission, median (IQR)	19 (14-26)	20 (15-26)	19 (14-25)
Glasgow Coma Scale score on ICU admission, median (IQR)	14 (11-15)	14 (11-15)	14 (11-15)
Intubation	65.5 (4,553)	66.2 (3,264)	64.9 (4,195)
Invasive ventilation	68.3 (4,747)	68.8 (3,393)	67.8 (4,387)
Duration, median hours (IQR)	51 (18-133)	62 (25-143)	50 (18-132)
Non-invasive ventilation	13.1 (913)	16.2 (798)	13.6 (878)
Duration, median hours (IQR)	24 (8-63)	28 (9-68)	24 (6-65)
ICU length of stay, median days (IQR)	3.7 (1.8-7.7)	4.3 (2.4-8.3)	3.7 (1.8-7.6)
Hospital length of stay, median days (IQR)	13.3 (6.1-29.5)	13.9 (6.8-30.0)	13.2 (6.1-29.3)
ICU mortality	14.1 (981)	12.2 (601)	12.9 (837)
Hospital mortality	21.0 (1,462)	19.9 (979)	19.5 (1,260)

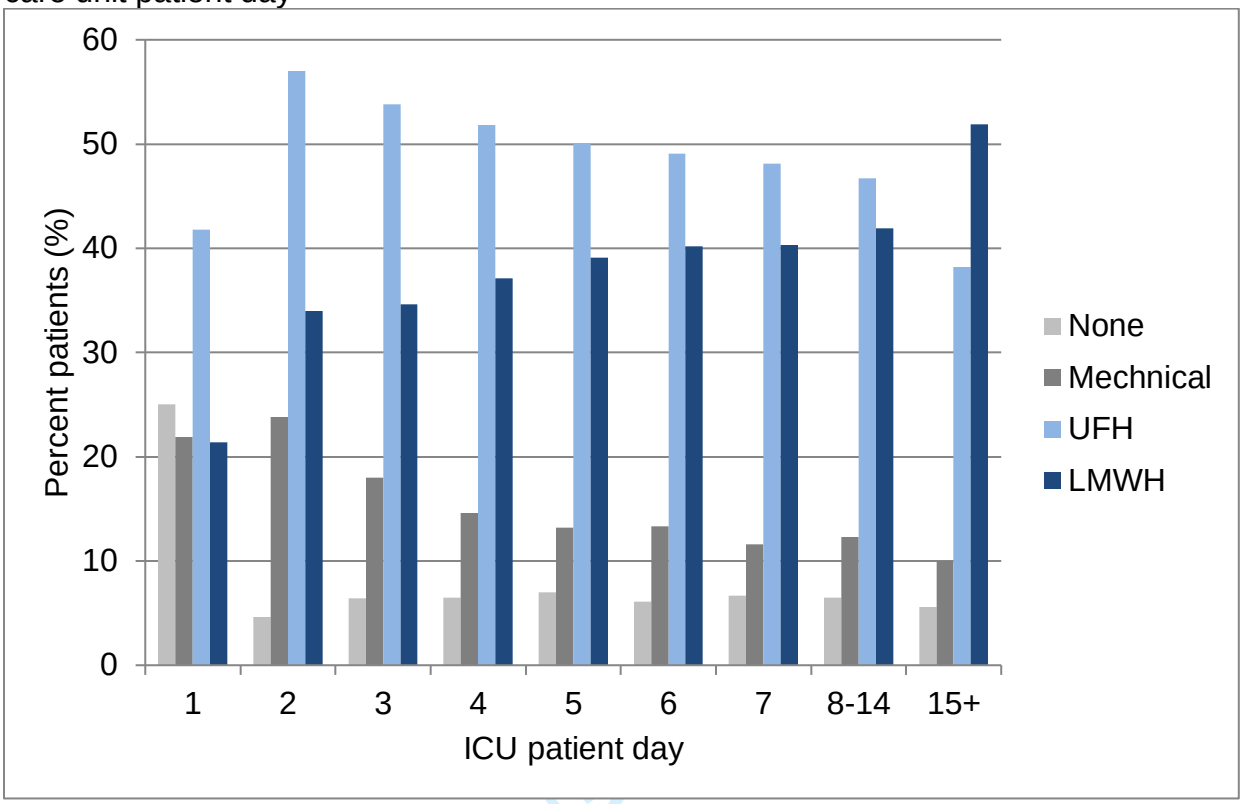
Abbreviations: **AIDS**=autoimmune deficiency syndrome, **APACHE II**=Acute Physiology and Chronic Health Evaluation II, **ICU**=intensive care unit, **IQR**=interquartile range,

Supplemental Content 4. Flow of patients



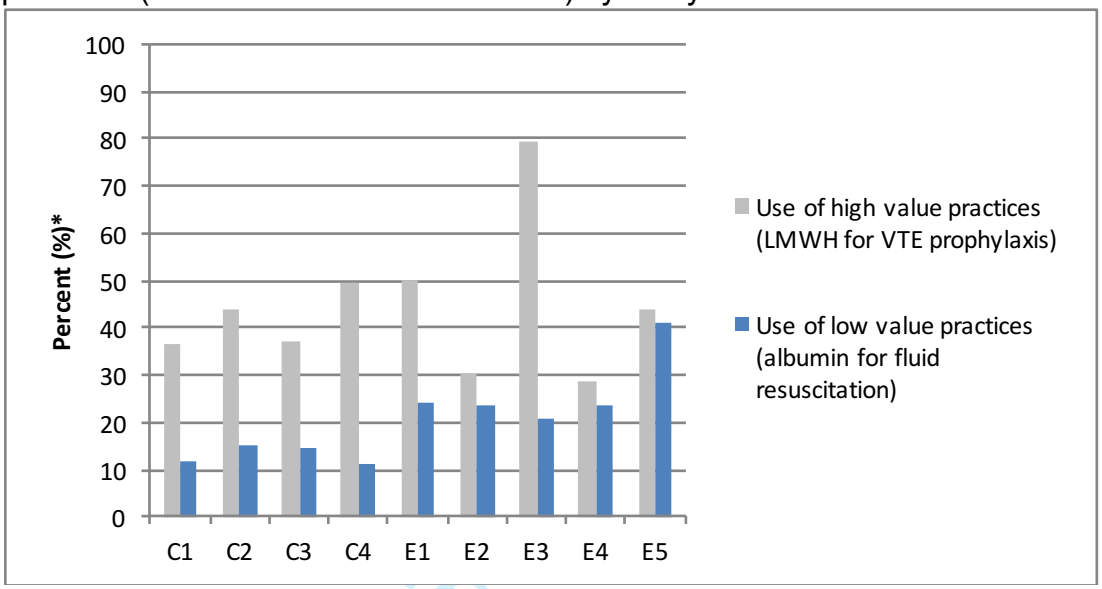
Footnote: Adoption cohort = Recommended to receive low molecular weight heparin for venous thromboembolism prophylaxis; de-adoption cohort = Recommended to NOT receive albumin for fluid resuscitation

Supplemental Content 5. Venous thromboembolism prophylaxis by intensive care unit patient day



Footnote: Percent of patients may add to greater than 100% because patients may have received more than one form of venous thromboembolism prophylaxis on a given patient day.
Abbreviation: ICU=intensive care unit, LMWH=low molecular weight heparin, UFH=unfractionated heparin

Supplemental Content 6. The use of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and the use of low value practices (albumin for fluid resuscitation) by study intensive care unit



Footnote: all "C" sites indicate ICU in Calgary and all "E" sites indicate ICU in Edmonton

*% of patient-days for VTE prophylaxis and % of patients for albumin

Supplemental Content 7. Survey participant characteristics

Professional group	**% (N)**
Attending physician	24.7 (64)
Fellow	6.2 (16)
Resident	12.4 (32)
Nurse practitioner	5.0 (13)
Nurse manager / charge nurse	10.0 (26)
Nurse educator	8.5 (22)
Bedside nurse	23.9 (62)
Pharmacist	9.3 (24)
Years worked in ICU	Median (IQR)
Attending physician	14.0 (9.8-22.0)
Clinical fellow	1.8 (1.0-2.3)
Resident	0.3 (0.1-1.0)
Nurse practitioner	15.0 (9.0-20.0)
Nurse manager / charge nurse	11.5 (7.3-18.8)
Nurse educator	19.0 (10.3-21.5)
Bedside nurse	7.5 (2.5-12.0)
Pharmacist	5.3 (3.0-10.8)
Years worked in healthcare	Median (IQR)
Attending physician	19.0 (14.8-25.3)
Clinical fellow	8.0 (7.0-9.5)
Resident	3.0 (2.0-5.1)
Nurse practitioner	15.0 (12.0-25.0)
Nurse manager / charge nurse	16.5 (12.5-24.0)
Nurse educator	21.0 (13.0-26.0)
Bedside nurse	10.0 (6.0-16.0)
Pharmacist	10.5 (6.1-14.3)

BMJ Open

Barriers and facilitators to adopting high value practices and de-adopting low value practices in Canadian Intensive Care Units: A multi method study

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Title: Barriers and facilitators to adopting high value practices and de-adopting low value practices in Canadian Intensive Care Units: A multi method study

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ABSTRACT

Objective: To compare and contrast illustrative examples of the adoption of high value practices and the de-adoption of low value practices.

Design: 1) Retrospective, population-based audit of low molecular weight heparin (LMWH) for venous thromboembolism (VTE) prophylaxis (high value practice) and albumin for fluid resuscitation (low value practice) and 2) Cross-sectional survey of healthcare providers.

Setting: Data were collected from nine adult medical-surgical ICUs in two large Canadian cities. Patients are managed in these ICUs by a group of multi-professional and multi-disciplinary healthcare providers.

Participants: Participants included 6946 ICU admissions and 309 healthcare providers from the same ICUs.

Main Outcome Measures: 1) The use of LMWH for VTE prophylaxis (percent ICU days) and albumin for fluid resuscitation (percent of patients); and 2) provider knowledge of evidence underpinning these practices, and barriers and facilitators to adopt and de-adopt these practices.

Results: LMWH was administered on 38.7% of ICU days, and 20.0% of patients received albumin.

Most participants had knowledge of evidence underpinning VTE prophylaxis and fluid resuscitation (59.1% and 84.2%, respectively). Providers perceived these practices to be followed. The most commonly reported barrier to adoption was insufficient knowledge/understanding (32.8%), and to de-adoption was clinical leader preferences (33.2%). On-site education was the most commonly identified facilitator for adoption and de-adoption (67.8% and 68.6%, respectively).

Conclusions: Despite knowledge of and self-reported adherence to best practices, the audit demonstrated opportunity to improve. Provider-reported barriers and facilitators to adoption and de-adoption are broadly similar.

KEY WORDS: Intensive Care; Appropriateness, Under-use and Over-use; Healthcare System; Quality Improvement

STRENGTHS & LIMITATIONS

- A strength of this study is the use of mixed-methods to comprehensively compare adoption of high value practices and de-adoption of low value practices in the ICU.
- Another strength is the use of population-based data to capture current clinical practices.
- The survey used to assess barriers and facilitators of the two illustrative practices was derived from a validated survey instrument.

- The survey used was simple and designed to garner a representative perspective from all provider professions and therefore captured key concepts, but not granular data.

INTRODUCTION

Optimizing the quality of care[1] is of particular importance in the intensive care unit (ICU) due to the acuity of patient illness and substantial resources required to care for these patients. However, practice change (adopting high value practices or de-adopting low value practices) can lag behind the publication of evidence hindering delivery of evidence-based practices and may be different when adopting or de-adopting practices.[2, 3] To minimize the latency for change, it is important to find ways to improve the implementation of evidence-based practices.

A growing body of evidence has evaluated barriers and facilitators for adopting high value practices (effective at improving outcomes).[4-7] Substantially less is known about the barriers and facilitators for de-adopting low value practices (ineffective at improving outcomes or harmful), and how they compare to those for adopting high value practices.[8, 9] De-adoption, also known by several other terms such as disinvestment and de-implementation,[8] is the discontinuation of a practice that has been previously adopted.[10] Some have suggested that the adoption of high value practices and de-adoption of low value practices involves similar processes and common facilitators and barriers;[11, 12] however, others suggest that the two are clearly distinct.[9, 13] There has been limited comparative evaluation of adoption and de-adoption and this is an important knowledge gap given the growing number of initiatives aimed at de-adopting low value practices.[13-16]

The objective of this study was to describe illustrative example practices of the adoption of a high value practice (use of low molecular weight heparin [LMWH] instead of unfractionated heparin [UFH] for venous thromboembolism prophylaxis [VTE] and the de-adoption of a low value practice (albumin for fluid resuscitation) in the ICU. The results of this study prompted a subsequent implementation study to improve these two practices. The audit data identified important opportunities to improve clinical care, and the perceived barriers and facilitators identified in the survey were used to inform the development of interventions.

METHODS

Study design

This multi-method observational study included: 1) a retrospective cohort study of patients admitted to ICUs to describe current VTE prophylaxis and fluid resuscitation practices, and 2) a cross-sectional survey of ICU healthcare providers to examine: knowledge of evidence underpinning these two practices, and perceived barriers and facilitators to adopt LMWH for VTE prophylaxis and de-adopt albumin for fluid resuscitation.

Setting

All data were collected from nine adult medical-surgical ICUs in the two largest cities in a Canadian province (population of 4.1 million). A single health services provider is responsible for the provision of all hospital-based care in the province and uses a single formulary across all ICUs (clinical practices may differ between cities and sites).

ICU patients are managed by a multi-disciplinary and multi-professional group of healthcare providers, including (but not limited to): physicians, medical trainees (clinical fellows and residents), nurse practitioners (NPs with prescribing privileges), pharmacists, and nurses (managers, educators, bedside).

Audit of current practices

Participants

We included patients admitted to nine adult medical-surgical ICUs between January 1, 2014 and December 31, 2014. For analyses, patients were grouped into two cohorts.

1) The adoption cohort consisted of patients without a contraindication for pharmacological VTE prophylaxis where according to international and local guidelines LMWH should be prescribed.[17-21] Contraindications to pharmacological prophylaxis included a diagnosis potentially associated with a high risk of bleeding (Supplemental Content 1), daily assessed platelet count <50 x10^9/L, INR ≥2, PTT ≥55 seconds, or receipt of therapeutic anti-coagulation.

2) The de-adoption cohort consisted of patients without an indication for use of albumin for fluid resuscitation and where according to the current evidence-base albumin should not be used for fluid resuscitation.[22-25] Potential indications for albumin included documented liver disease (cirrhosis or hepatic failure), or receipt of plasma exchange.[26-29] The two study cohorts were drawn from the same patient population and patients satisfying both sets of clinical indications were included in both cohorts.

Data source

All nine ICUs employ a shared integrated, prospective, clinical information system that captures and delivers multimodal patient data (demographic, clinical, outcome) in real time to the bedside (eCritical MetaVision, iMDsoft, MetaVision), and is also a repository and clinical analytics system that stores these data (eCritical TRACER) to support quality improvement and clinical research. eCritical TRACER was used to extract all data.

Variables

Patient and ICU demographic variables included age, sex, comorbidities, admission type, disease severity (APACHE II score), ICU and hospital length of stay, ICU and hospital mortality. Data abstracted included: 1) type of VTE prophylaxis (mechanical included antiembolic stockings and sequential compression devices, and pharmacological included unfractionated heparin [UFH] and LMWH), 2) ICU day that VTE prophylaxis was administered, 3) if the patient received albumin, 4) quantity (units) of albumin, and 5) ICU day that albumin was administered. An ICU day was defined as any portion of a day between 07:00 and 06:59, recognizing that follow-up time on admission day and discharge day may be less than 24 hours.

Data analysis

Descriptive statistics (means with standard deviations [SD], medians with interquartile ranges [IQR], frequencies with proportions) were used to describe the two cohorts. The proportion of admissions and ICU days with LMWH, UFH, and mechanical VTE

prophylaxis by ICU and ICU day; and with any albumin administration by ICU and patient were calculated to describe current clinical practices. The unit of analysis for our outcome for the adoption cohort (LMWH use) was patient days because VTE prophylaxis is a routine clinical practice that should be performed on a daily basis. Conversely, the unit of analysis for our outcome for the de-adoption cohort (albumin use) was per patient because fluid resuscitation is a sporadic event that is not part of routine daily patient care.

To examine potential associations between patient demographic and sites, and the use of the high value practice (LMWH) a multivariable generalized estimating equations (GEEs) logistic regression model with exchangeable correlation structure given daily measurements (clustering by patient) was used. To examine potential associations between demographic and site-level factors, and the use of the low value practice (albumin) a multivariable logistic regression model given a single measurement per patient was used.

Barriers and facilitators to adopting LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation

Survey development

The survey was modeled after previous work on adoption of LMWH for VTE prophylaxis,[30] and refined to include questions regarding fluid resuscitation. Because research around barriers and facilitators of de-adopting low value practices is in its

infancy[31] the evidence of barriers and facilitators for adopting high value practices was employed.

The survey was divided into four sections: participant demographic information, knowledge of the current evidence underpinning the best practices, and perceptions of barriers and facilitators to the use of the two illustrative examples of best practices (Supplemental Content 2).

The survey was pilot tested in two phases: Phase 1) Seven providers completed the survey and identified unnecessary, missing, or poorly worded items. The survey was modified and pilot tested with 12 additional ICU providers (1 attending physician, 2 residents, 1 clinical fellow, 1 nurse practitioner, 1 nurse manager/charge nurse, 1 nurse educator, 2 bedside nurses, and 3 pharmacists). Phase 2) Providers completed the survey twice (7-10 days apart) and an additional brief questionnaire to rate the clinical sensibility of the survey. Test-retest reliability of the survey demonstrated a mean intraclass correlation coefficient (ICC) of 0.66 (SD 0.47) for continuous responses and a mean proportion of agreement of 0.86 (SD 0.10) for categorical responses. The low ICC for continuous responses is due to low variability in responses for questions relating to knowledge of best practices. The participants agreed that the survey had face validity (100%), content validity (92%), clarity (92%), utility (100%), discriminability (75%), and minimal redundancy (100%).

Participants

Healthcare providers (as described in Setting) that cared for patients in the nine ICUs were invited by email to participate in the study. Invitations to participate were sent to healthcare providers by the principal investigators or by a local clinical leader and included a link to the electronic survey (Fluid Survey) or were provided a paper copy if requested. Weekly reminders were sent for three weeks. Providers that responded to the survey were offered entry into a draw for one of three $20 coffee gift cards.

Data Analysis

We used descriptive statistics to describe demographic features of participants, knowledge of best practices, perceived barriers to adopting high value practices and de-adopting low value practices, perceived facilitators to encourage adopting high value practices and de-adopting low value practices. Barriers and facilitators to the use of best practices were described overall, and by professional group. Professions were categorized into three groups for analysis: 1) Physicians/NPs (those who prescribe), 2) Nurses (those who administer), and 3) Pharmacists (those who advise prescribers). Chi-squared tests were used to test for statistical significance between groups.

Patient and public involvement

Patient and family representatives were members of a committee that identified and prioritized research questions for improving the care of critically ill patients.[32] LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation were two of the research questions identified by this committee. Patients were not involved in the

design, the recruitment and conduct of this study. The results of this study have been disseminated to patient and family advisors through oral presentations.

Ethical considerations

This study was approved by the University of Calgary Conjoint Health Research Ethics Board (REB14-0992 and REB15-2147) and the University of Alberta Research Ethics Board (Pro00056709 and Pro00060650).

RESULTS

Audit of current practices

There were 6,946 ICU admissions during the study period, from 6,299 unique patients. Patient characteristics are presented in Supplemental Content 3.

The adoption cohort consisted of 4,931 admissions (71.0% of all admissions) without a contraindication to pharmacological VTE prophylaxis, and the de-adoption cohort consisted of 6,467 admissions (93.1%) without a potential indication for albumin (Supplemental Content 4).

During the ICU stay LMWH was given on 38.7% of ICU days, UFH on 45.3% of ICU days and mechanical prophylaxis (exclusive of pharmacological prophylaxis) on 7.7% of ICU days. The type of VTE prophylaxis administered varied throughout patients' ICU stay; administration of mechanical devices and UFH decreased over the course of the ICU stay while administration of LMWH increased (Supplemental Content 5).

6,804 units of albumin were administered to 20.0% of the 6,467 admissions without documented liver disease or receipt of plasma exchange. Among those receiving at least 1 unit of albumin, the median number of units per patient was 3 (IQR=1.0-6.0). Albumin was administered on 6.5% of ICU days.

When controlling for demographic and site-level factors, the odds of receiving LMWH for VTE prophylaxis and not receiving albumin for fluid resuscitation were significantly lower for those patients with higher severity of illness (APACHE II score). The odds of receiving LMWH for VTE prophylaxis were significantly higher for patients with non-surgical admissions compared to those with elective surgical admissions (odds ratio = 1.34 (95% confidence interval 1.08-1.66); Table 1). There were significant differences in the odds of using LMWH for VTE prophylaxis, and not using albumin for fluid resuscitation across ICUs (Supplemental Content 6), and when controlling for patient-level factors some of these differences persisted especially with regards to the use of LMWH for VTE prophylaxis (Table 1).

Table 1. Association between patient demographic and sites, and the use of LMWH for VTE prophylaxis and not using albumin for fluid resuscitation

	Appropriate VTE prophylaxis OR (95% CI)*	**Appropriate fluid resuscitation OR (95% CI)****
Age	NS†	0.999 (0.999-1.00)
Female	NS†	NS†
Any comorbidity	NS†	NS†
Admission type		
Elective surgery	1.00 (reference group)	1.00 (reference group)
Emergent surgery	1.19 (0.92-1.53)	0.92 (0.88-0.95)
No surgery	1.34 (1.08-1.66)	1.02 (0.98-1.05)
APACHE II Score (ICU admission)	0.958 (0.951-0.965)	0.989 (0.988-0.990)

Site		
C1	1.00 (reference group)	1.00 (reference group)
C2	1.32 (1.07-1.64)	0.96 (0.92-1.00)
C3	1.13 (0.89-1.46)	0.98 (0.94-1.03)
C4	1.48 (1.15-1.90)	0.98 (0.93-1.02)
E1	2.12 (1.66-2.73)	0.90 (0.86-0.95)
E2	0.86 (0.71-1.05)	0.90 (0.87-0.92)
E3	7.26 (5.46-9.65)	0.92 (0.87-0.97)
E4	0.76 (0.63-0.92)	0.88 (0.85-0.91)
E5	1.61 (1.23-2.10)	0.75 (0.72-0.79)

Footnote: all "C" sites indicate ICU in Calgary and all "E" sites indicate ICU in Edmonton

*multivariable generalized estimating equations (GEEs) logistic regression model with exchangeable correlation structure given daily measurements (clustering by patient); "appropriate" considered *use of LMWH*

**standard multivariable logistic regression model given single measurement per patient; "appropriate" considered *not using albumin*

†NS = non-significant, removed from model

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Participants

83.8% (259 of 309) of participants responded; physicians/NPs (48.3%), nurses (42.5%), and pharmacists (9.3%). Participants worked in healthcare for a median of 13 years (IQR=7.1-20.0) and in critical care for a median of 8 years (IQR=3.0-15.0; Supplemental Content 7).

Knowledge of evidence

Most participants reported that LMWH was most effective at preventing deep vein thrombosis and pulmonary embolism; and that crystalloids were most effective for fluid resuscitation (Table 2). Perceptions regarding the effectiveness of VTE prophylaxis varied by professional group, as did perceptions regarding the risks of harm (Table 2).

Perceptions regarding effectiveness of albumin for fluid resuscitation and risks of harm associated with each form of fluid resuscitation did not vary by professional group but perceptions regarding the risk of fluid overload did (Table 2).

It was perceived that both best practices were being followed in the ICUs where the participants practiced (Table 2).

Table 2. Knowledge of best practices for VTE prophylaxis and fluid resuscitation

	% (N)			
Survey question	**Overall N=259**	**Physicians/NPs 48.3% (N= 125)**	**Nurses 42.5% (N= 110)**	**Pharmacists 9.3% (N= 24)**
What form(s) of prophylaxis is/are most effective at preventing deep vein thrombosis?*				
LMWH only	59.1 (153)	63.2 (79)	51.8 (57)	70.8 (17)
UFH only	4.3 (11)	2.4 (3)	7.3 (8)	0.0 (0)
LMWH & UFH	16.2 (42)	24.0 (30)	5.5 (6)	25.0 (6)
Mechanical only	1.9 (5)	0.0 (0)	4.6 (5)	0.0 (0)
(LMWH or UFH) and Mechanical	15.1 (39)	8.0 (10)	25.5 (28)	4.2 (1)
Unsure only	3.5 (9)	2.4 (3)	5.5 (6)	0.0 (0)
What form(s) of prophylaxis is/are most effective at preventing pulmonary embolism? *				
LMWH only	56.8 (147)	72.0 (90)	33.6 (37)	83.3 (20)
UFH only	18.2 (47)	1.6 (2)	40.9 (45)	0.0 (0)
LMWH & UFH	12.7 (33)	20.8 (26)	3.6 (4)	12.5 (3)
Mechanical only	0.4 (1)	0.0 (0)	0.9 (1)	0.0 (0)
(LMWH or UFH) & Mechanical	8.5 (22)	3.2 (4)	15.5 (17)	4.2 (1)
Unsure only	3.5 (9)	2.4 (3)	5.5 (6)	0.0 (0)
Which form(s) of prophylaxis is/are most cost effective?*				
LMWH only	51.0 (132)	70.4 (88)	22.7 (25)	79.2 (19)
UFH only	15.4 (40)	12.8 (16)	20.0 (22)	8.3 (2)
LMWH & UFH	4.3 (11)	5.6 (7)	0.9 (1)	12.5 (3)
Mechanical only	10.0 (26)	4.8 (6)	18.2 (20)	0.0 (0)
(LMWH or UFH) & Mechanical	2.7 (7)	0.0 (0)	6.4 (7)	0.0 (0)
Unsure only	16.6 (43)	6.4 (8)	31.8 (35)	0.0 (0)
Which form(s) of pharmacological prophylaxis has/have the lowest risk of bleeding?†				
LMWH only	57.5 (149)	47.2 (59)	69.1 (76)	58.3 (14)
UFH only	24.7 (64)	32.8 (41)	18.2 (20)	12.5 (3)
LMWH & UFH	5.0 (13)	6.4 (8)	0.0 (0)	20.8 (5)
Unsure only	12.7 (33)	13.6 (17)	12.7 (14)	8.3 (2)
Which form(s) of pharmacological prophylaxis has/have the lowest risk of heparin induced thrombocytopenia?*				

LMWH only	86.1 (223)	94.4 (118)	74.6 (82)	95.8 (23)
UFH only	6.6 (17)	3.2 (4)	11.8 (13)	0.0 (0)
LMWH & UFH	0.4 (1)	0.0 (0)	0.0 (0)	4.2 (1)
Unsure only	7.0 (18)	2.4 (3)	13.6 (15)	0.0 (0)
To what extent do you think best practices are followed for preventing DVT/PE in your ICU? 0=never and 7=always, Median (IQR)				
	6 (5-6)	6 (5-6)	6 (6-7)	6 (5-6)
Survey question	**Overall N=259**	**Physicians/NPs 48.3% (N= 125)**	**Nurses 42.5% (N= 110)**	**Pharmacists 9.3% (N= 24)**
What form(s) of IV fluids is/are most effective for fluid resuscitation?‡				
Albumin only	3.5 (9)	2.4 (3)	5.5 (6)	0.0 (0)
Crystalloids only	84.2 (218)	83.2 (104)	82.7 (91)	95.8 (23)
Albumin & Crystalloids	8.5 (22)	9.6 (12)	9.1 (10)	0.0 (0)
Unsure only	3.9 (10)	4.8 (6)	2.7 (3)	4.2 (1)
Which form(s) of IV resuscitation fluids are most cost effective? ‡				
Albumin only	0.4 (1)	0.0 (0)	0.9 (1)	0.0 (0)
Crystalloids only	94.6 (245)	94.4 (118)	95.5 (105)	91.7 (22)
Albumin & Crystalloids	0.4 (1)	0.8 (1)	0.0 (0)	0.0 (0)
Unsure only	4.6 (12)	4.8 (6)	3.6 (4)	8.3 (2)
Which form(s) of IV resuscitation fluids has the lowest risk of fluid overload? *				
Albumin only	47.1 (122)	32.8 (41)	69.1 (76)	20.8 (5)
Crystalloids only	29.7 (77)	36.8 (46)	23.6 (26)	20.8 (5)
Albumin & Crystalloids	1.9 (5)	3.2 (4)	0.0 (0)	4.2 (1)
Unsure only	21.2 (55)	27.2 (34)	7.3 (8)	54.2 (13)
Which form(s) of IV resuscitation fluids has the lowest risk of infectious disease? ‡				
Albumin only	2.7 (7)	1.6 (2)	4.6 (5)	0.0 (0)
Crystalloids only	86.5 (224)	87.2 (109)	87.3 (96)	79.2 (19)
Albumin & Crystalloids	0.8 (2)	0.8 (1)	0.9 (1)	0.0 (0)
Unsure only	10.0 (26)	10.4 (13)	7.3 (8)	20.8 (5)

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To what extent do you think best practices are followed for prescribing fluid boluses in your ICU? 0=never and 7=always; Median (IQR)				
	6 (5-6)	5 (5-6)	6 (5-6)	5 (5-6)

[1]The order of the survey items are as presented in this table.

[2]Evidence suggests the efficacy of LMWH for deep vein thrombosis is similar to or better than UFH.[18, 19, 33, 34] Evidence suggests that LMWH is more efficacious than UFH for preventing pulmonary embolism, has a lower incidence of heparin induced thrombocytopenia, and a similar or lower risk of bleeding.[18, 19, 33, 34]

[3]Evidence suggests that LMWH is more cost effective than UFH.[18]

[4]Evidence suggests that albumin and crystalloids are similarly effective for fluid resuscitation.[21, 24, 26] Evidence suggests that albumin has a higher risk of infectious disease transmission than crystalloids and is less cost-effective than crystalloids.

Abbreviations: **IQR** = interquartile range (p25 - p75), **LMWH** = low molecular weight heparin, **N** = number, **NP** = nurse practitioner, **UFH** = unfractionated heparin, ***** = responses varied by professional group (p<0.001), **†**= responses varied by professional group (p=0.01), **‡**= responses did not vary by professional group (p>0.05)

Barriers to adopting LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation

Barriers to adoption and de-adoption were reported by 65.2% and 64.9% of respondents, respectively. The most commonly reported perceived barriers to adopting LMWH for VTE prophylaxis were insufficient knowledge or understanding, ICU culture, and no clinical guidelines (Figure 1). The most commonly reported barriers to de-adopting albumin for fluid resuscitation were a strong clinical preference of the local clinical leaders in the ICUs, ICU culture, and insufficient knowledge or understanding (Figure 1). Reported barriers differed between professional groups for both adoption (Figure 2a) and de-adoption (Figure 2b).

Facilitators to adopting LMWH for VTE prophylaxis and de-adopting albumin for fluid resuscitation

On site education and pre-set orders were perceived to be the most commonly reported facilitator of both adoption and de-adoption (Figure 3). Verbal reminders from pharmacists to physicians was commonly reported as a perceived facilitator for adopting LWMH for VTE prophylaxis. A local leader championing the practice was commonly reported as a perceived facilitator for de-adopting albumin for fluid resuscitation (Figure 3). There was no variability by professional group.

DISCUSSION

The present study identified opportunities to improve the use of best practices for VTE prophylaxis (adopting the high value practice of LMWH) and fluid resuscitation (de-adopting the low value practice of albumin). Our audit data demonstrated that current practice does not reflect providers' understanding of the evidence for these practices. The use of the best practice for these two illustrative examples were less likely for patients with greater severity of illness and varied across institutions. The perceived barriers and facilitators to adoption and de-adoption were broadly similar.

Are de-adoption and adoption just the flip-side of the same coin? There is substantial literature describing the adoption of high value practices, but much less is known about de-adoption of low value practices.[8] Science can inform clinical practice through discovery resulting in adoption of a new practice, replacement resulting in a practice update, and reversal resulting in de-adoption of an existing practice. It is only recently that the last concept, de-adopting low value practices, has been debated in journals and by professional societies.[13, 14, 16] The practical implication is that there is limited evidence to inform whether the barriers and facilitators for adoption and de-adoption are similar or sufficiently distinct to warrant different approaches.[9, 11-13] Our study adds to the limited evidence base by suggesting that culture or organizational factors, provider characteristics, and patient characteristics are perceived to be important barriers and facilitators that may play broadly similar roles in adoption and de-adoption.[11, 12]

Knowledge translation (KT) interventions are strategies to improve the synthesis, dissemination, exchange, and application of evidence to improve health.[5] KT interventions tailored to the specific barriers and facilitators of an innovation and the local context are more likely to effect change.[5, 6] Our study provides insight into the perceived barriers and facilitators of adopting high value practices (LMWH for VTE prophylaxis) and de-adopting low value practices (albumin for fluid resuscitation) within ICUs, which should be taken into consideration when designing KT interventions. Interestingly, despite knowledge of the evidence underlying the illustrative example practices, providers perceived insufficient knowledge or understanding to be a barrier and perceived education to be a facilitator to both adopting high value practices and de-adopting low value practices. These barriers and facilitators are consistent with a systematic review that suggests the most effective KT interventions in the ICU employ a combination of education and protocols.[35] While consistent with previous KT studies, this finding is paradoxical. It is possible that while knowledgeable, providers' confidence in applying their knowledge clinically was low and they believed education to be the intervention needed to improve their confidence in applying their knowledge. Furthermore, confidence in applying new evidence in clinical practice may be particularly challenging in the care of severely ill patients. This hypothesis is supported by two of our findings: 1) the use of LMWH for VTE prophylaxis and not using albumin for fluid resuscitation was inversely associated with severity of patient illness and 2) the use of LMWH and not using albumin increased as the patient became more stable (over ICU stay). Potential hypotheses to explain these observations include that clinicians may employ conservative decision-making (use

more familiar practices) or unintendedly neglect to use best practices when caring for sicker patients, but this need further exploration. The implications are that KT interventions should consider clinician heuristics that are likely to be influenced by the nature and severity of patient illness.

Our study suggests that factors other than knowledge may contribute to the successful adoption of high value practices and de-adoption of low value practices, which includes culture, providers, and the innovation. These factors have previously been identified within the context of the ICU. [2, 36-41] ICU culture and local clinical leader preferences were among the most commonly endorsed barriers to adopting high value practices and de-adopting low value practices in this study and in our study. This is highlighted by the variation in the use of LMWH between ICUs, even when patient level factors were taken into consideration. Interestingly, this finding was less pronounced for de-adoption, which has been previously reported.[9] Culture, also referred to as organizational context, is a frequently cited barrier to evidence-based medicine and can have a profound effect on clinical practice.[7, 42] However, few studies have systematically evaluated the effect of culture on adopting high value practices and de-adopting low value practices, and implementation studies infrequently account for the effect of culture on their practice change interventions.[43] Similarly, the professional role of the provider is not often contextualized but may be important (e.g., should pharmacists and nurses be targeted in KT interventions designed to change the prescribing patterns of physicians and if so how?).[44] This

may be especially relevant as healthcare delivery becomes increasingly multi-professional and team-based as illustrated in our setting (ICU).

The characteristics of innovations themselves may influence change in clinical practice. Evidence suggests that if the innovation being adopted is congruent with clinical practice beliefs it can facilitate adoption.[7] Furthermore, the quality, quantity, and stability of available evidence to support the adoption or de-adoption of an innovation is likely important.[45] Although most providers in our study were aware of the evidence to support the adoption of LMWH for VTE prophylaxis and de-adoption of albumin for fluid resuscitation, they may not have perceived the evidence to be sufficient to warrant practice change. A growing awareness of challenges with reproducing scientific evidence and clinician experience with practice reversals[2] may result in more conservative provider behavior and slower practice change in response to new evidence. The suboptimal prescribing practices observed in our study likely represent a combination of all these factors.

One limitation of this study is that the survey used was imperfect. The results of the self-reported survey reflect perceived modifiers of practice among providers rather than factors shown to influence practice patterns as identified in observational studies.[46] The survey was purposefully designed to be simple and accessible to garner a representative perspective from all provider professions and therefore captured key concepts, but not granular data. Nevertheless, the survey has been successfully used for a similar purpose by others;[30] was reliable and reported to have

good clinical sensibility. Alternative methodologies such as qualitative analyses of semi-structured interviews may have allowed for more in depth exploration of barriers and facilitators to adopting LMWH and de-adopting albumin. Finally, while this study was a provincial and multi-site it was constrained to ICUs, which should be taken into consideration when interpreting our findings beyond this setting.

In conclusion, our study provides several insights into similarities and differences between adoption of high value practices and de-adoption of low value practices. Both adoption and de-adoption of the illustrative example practices did not reflect healthcare providers' knowledge of the evidence. The use of best practices for both illustrative examples practices were less likely for patients with greater severity of illness and varied across institutions. We found that perceived barriers and facilitators are more similar than different between adoption and de-adoption, which suggests existing behavior change frameworks for adopting high value practices may also be applicable for de-adopting low value practices.

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DISCLOSURE OF CONFLICT OF INTERESTS

The authors declare that they have no competing interests.

DATA SHARING STATEMENT

Data will be provided upon request to the corresponding author (tstelfox@ucalgary.ca)

AUTHORS' CONTRIBUTIONS

Dr. Sauro contributed to the design and conceptualization of the study; analysis and interpretation of the data, drafting and revising the manuscript and gave approval of the final version of the manuscript. No conflicts of interest to declare.

Dr. Bagshaw contributed to the design and conceptualization of the study, interpretation of the data, providing feedback on the manuscript, and gave approval of the final version of the manuscript. No conflicts of interest to declare.

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Dr. Stelfox contributed to the design and conceptualization of the study, interpretation of the data, providing feedback on the manuscript, and gave approval of the final version of the manuscript. No conflicts of interest to declare.

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Figure 1. Barriers to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation)

Abbreviations: ICU: intensive care unit

Figure 2a. Barriers to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) by professional group.

Figure 2b. Barriers to the de-adoption of low value practices (albumin for fluid resuscitation) by professional group

Abbreviations: **ICU**=intensive care unit, **NP**=nurse practitioner

Figure 3. Facilitators to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation)

Abbreviation: **MD=**medical doctor, **QI=**quality improvement

Figure 1. Barriers to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation)

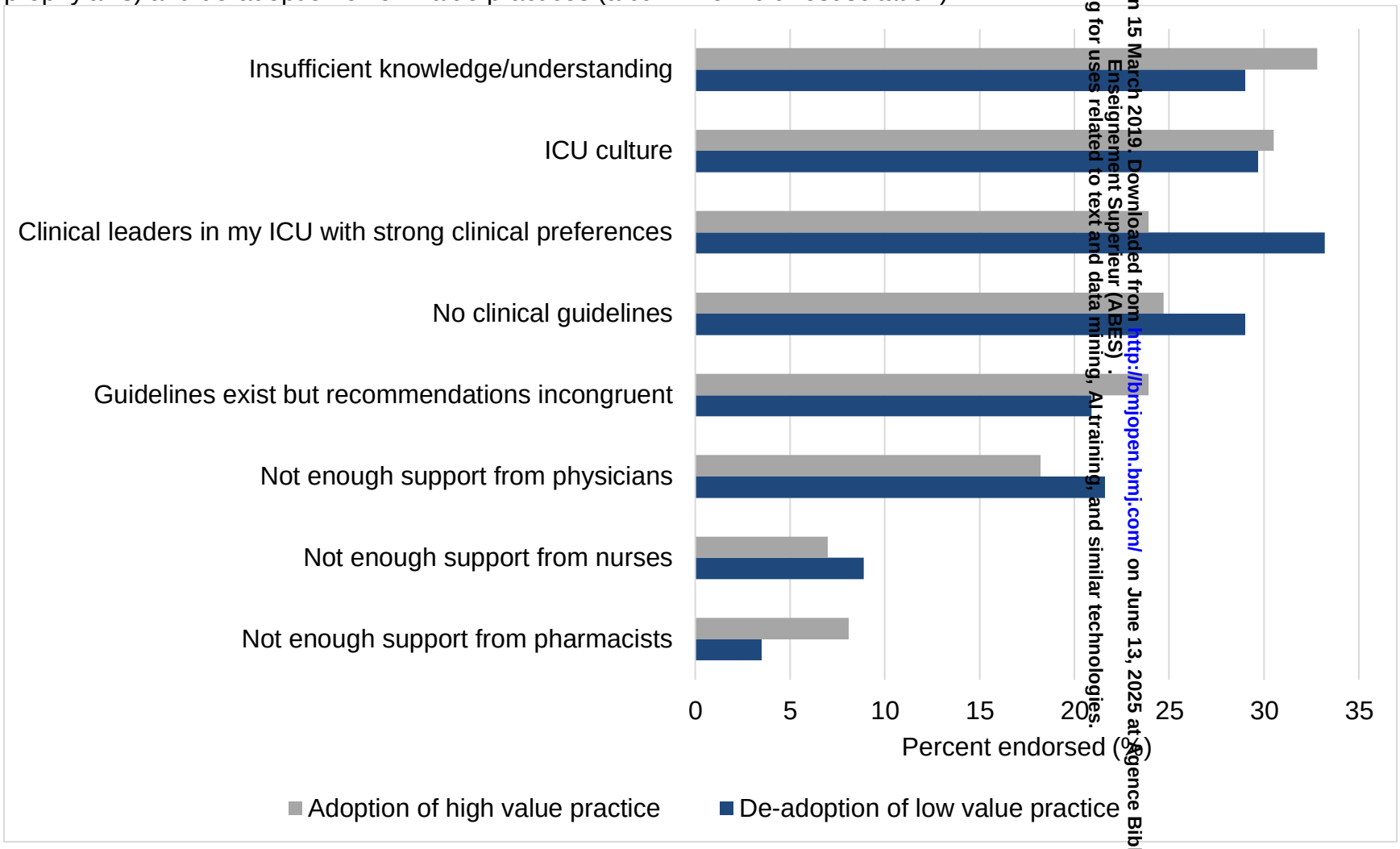
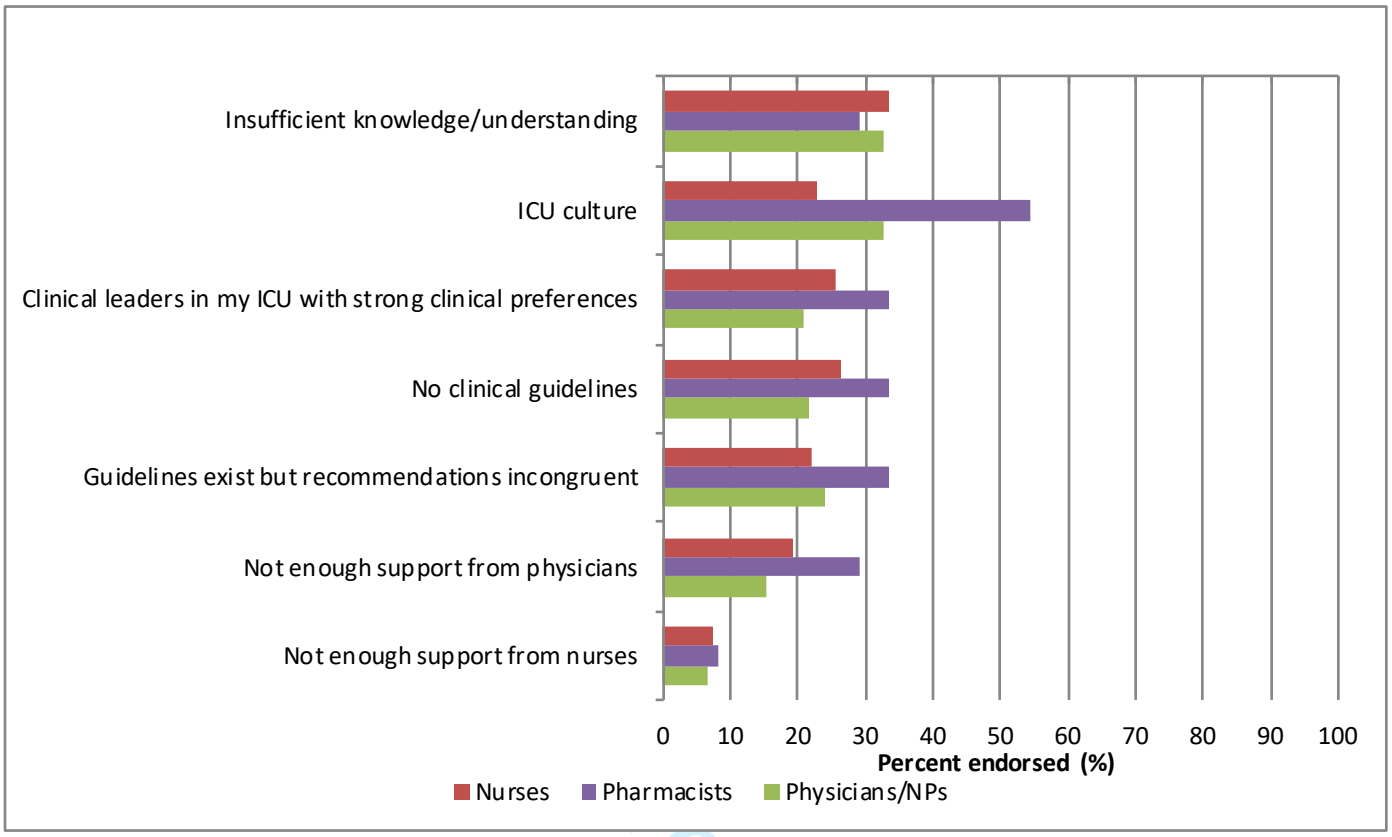
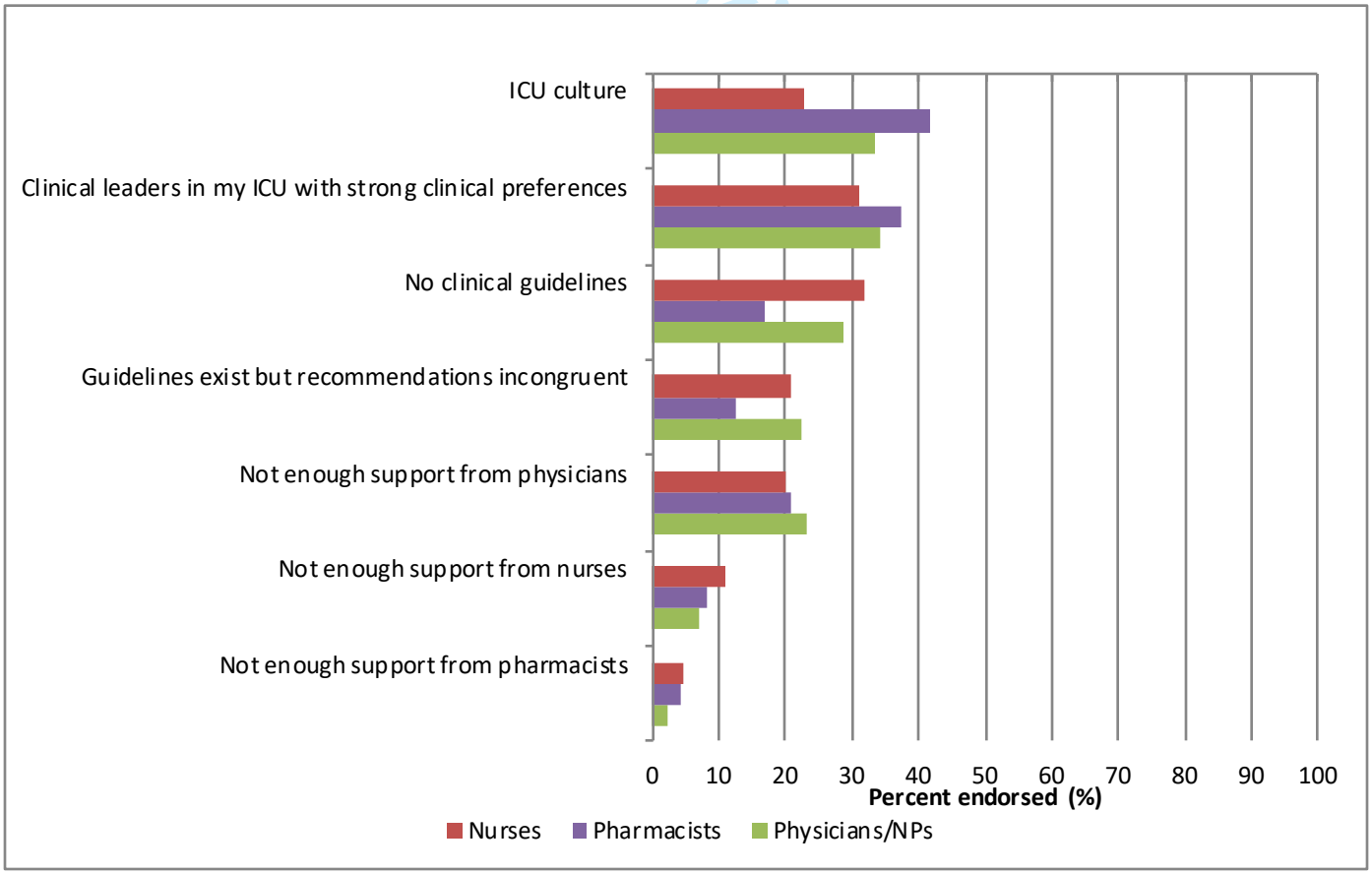


Figure 2. Barriers to adopting high value practices and de-adopting low value practices by profession

2.a) Barriers to adopting high value practices (LMWH for VTE prophylaxis) by professional group

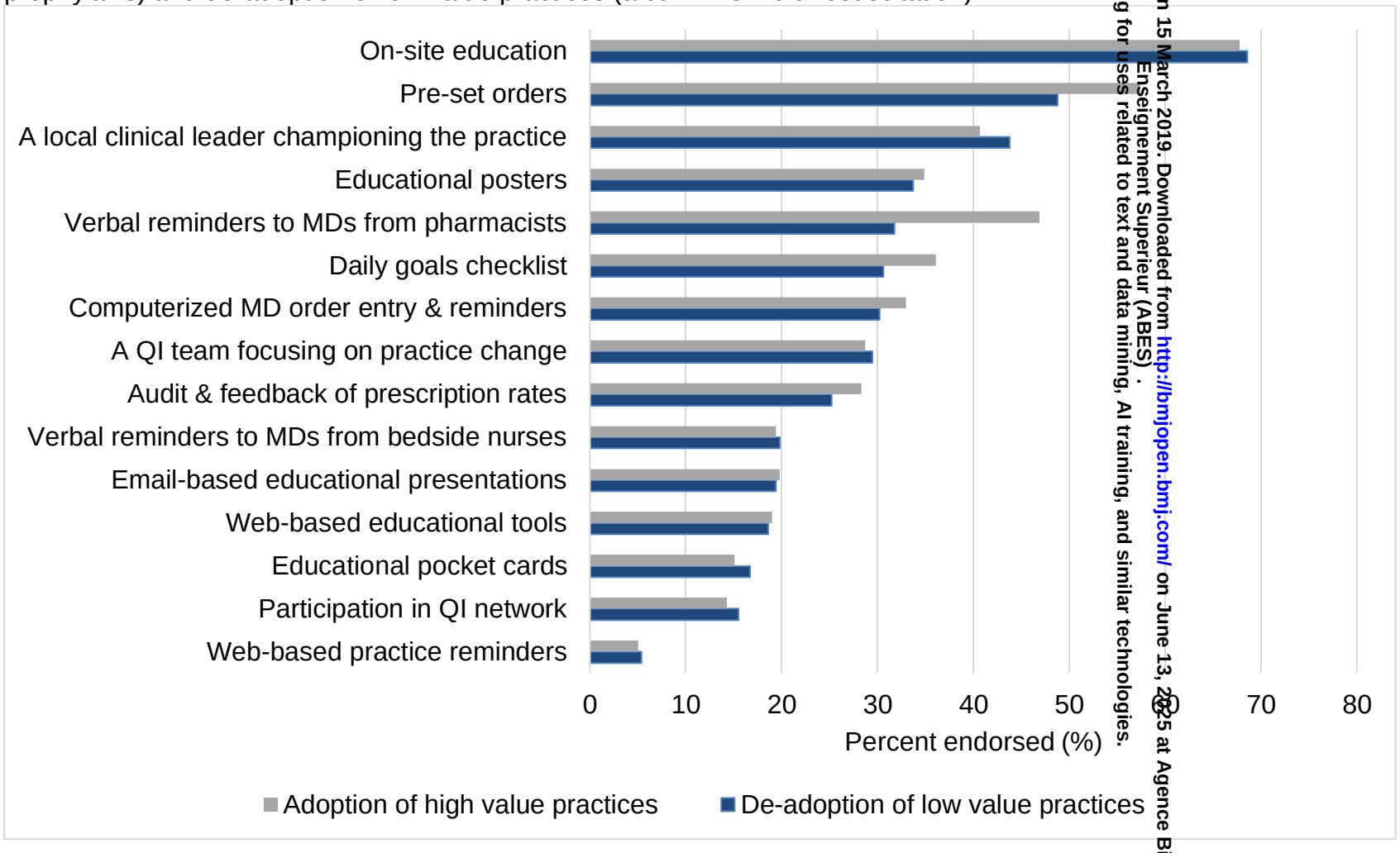


2.b) Barriers to de-adopting low value practices (albumin for fluid resuscitation) by professional group



Abbreviations: ICU=intensive care unit; NP=nurse practitioner; LMWH=low molecular weight heparin; VTE=venous thromboembolism

Figure 3. Facilitators to the adoption of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and de-adoption of low value practices (albumin for fluid resuscitation)



Abbreviation: **MD=**medical doctor, **QI**=quality improvement

Supplemental Content 1. List of diagnoses with a potential contraindication to receive pharmacological venous thromboembolism prophylaxis or indication for therapeutic anticoagulation*

Arteriovenous malformation, surgery for
Embolus, pulmonary
GI Vascular insufficiency
Grafts, removal of infected vascular
Neoplasm, neurologic
Neoplasm-cranial, surgery for (excluding transphenoidal)
Neoplasm-spinal cord surgery or other related procedures
Neurologic surgery, other
Subarachnoid hemorrhage/intracranial aneurysm
Subarachnoid hemorrhage/intracranial aneurysm, surgery for
Thrombosis, vascular (deep vein)
Transphenoidal surgery
Ulcer disease, peptic
Abdomen only trauma
Abdomen only trauma, surgery for
Abdomen/extremity trauma
Abdomen/extremity trauma, surgery for
Abdomen/face trauma
Abdomen/face trauma, surgery for
Abdomen/multiple trauma
Abdomen/multiple trauma, surgery for
Abdomen/pelvis trauma, surgery for
Abscess/infection-cranial, surgery for
Anastomosis, vascular
Aneurysm, abdominal aortic
Aneurysm, abdominal aortic; with dissection
Aneurysm, abdominal aortic; with rupture
Aneurysm, dissecting aortic
Aneurysm, thoracic aortic
Aneurysm, thoracic aortic; with dissection
Aneurysm, thoracic aortic; with rupture
Aneurysm/pseudoaneurysm, other
Aneurysms, repair of other (except ventricular)
Biopsy, brain
Bleeding, GI from esophageal varices/portal hypertension
Bleeding, GI-location unknown
Bleeding, lower GI
Bleeding, upper GI
Bleeding-lower GI, surgery for
Bleeding-other GI, surgery for
Bleeding-upper GI, surgery for

Burr hole placement
CABG alone, coronary artery bypass grafting
CVA, cerebrovascular accident/stroke
Chest/abdomen trauma
Chest/abdomen trauma, surgery for
Chest/extremity trauma
Chest/extremity trauma, surgery for
Chest/face trauma
Chest/face trauma, surgery for
Chest/multiple trauma
Chest/multiple trauma, surgery for
Chest/pelvis trauma
Chest/pelvis trauma, surgery for
Chest/spinal trauma
Chest/spinal trauma, surgery for
Chest/thorax only trauma
Chest/thorax only trauma, surgery for
Coagulopathy
Complications of prev. peripheral vasc. surgery, surgery for (i.e.ligation of bleeder, exploration and evacuation of hematoma, debridement, pseudoaneurysms, clots, fistula, etc.)
Complications of previous GI surgery; surgery for (anastomotic leak, bleeding, abscess, infection, dehiscence, etc.)
Complications of previous spinal cord surgery, surgery for
Cranioplasty and complications from previous craniotomies
Head (CNS) only trauma
Head (CNS) only trauma, surgery for
Head/abdomen trauma
Head/abdomen trauma, surgery for
Head/chest trauma
Head/chest trauma, surgery for
Head/extremity trauma
Head/extremity trauma, surgery for
Head/face trauma
Head/face trauma, surgery for
Head/multiple trauma
Head/multiple trauma, surgery for
Head/pelvis trauma
Head/pelvis trauma, surgery for
Head/spinal trauma
Head/spinal trauma, surgery for
Hematoma, epidural
Hematoma, epidural, surgery for
Hematoma, subdural
Hematoma, subdural, surgery for

Hematomas
Hemorrhage (for gastrointestinal bleeding GI-see GI system) (for trauma see Trauma)
Hemorrhage, intra/retroperitoneal
Hemorrhage, postpartum (female only)
Hemorrhage/hematoma, intracranial
Hemorrhage/hematoma-intracranial, surgery for
Hemorrhage/hemoptysis, pulmonary
Hemothorax
Pelvis/extremity trauma
Pelvis/extremity trauma, surgery for
Pelvis/face trauma
Pelvis/hip only trauma, surgery for
Pelvis/multiple trauma, surgery for
Pelvis/spinal trauma
Pericardial effusion/tamponade
Renal bleeding
Spinal cord only trauma, surgery for
Spinal cord surgery, other
Stereotactic procedure
Subarachnoid hemorrhage/arteriovenous malformation
Tamponade, pericardial

**Footnote:* The primary diagnoses were reviewed independently by two ICU physicians (HTS, DJN). The two ICU physicians provided their judgment to establish a conservative list of primary diagnoses in order to exclude patients that may have a contraindication for pharmacological VTE prophylaxis based on bleeding risk and an indication for therapeutic anticoagulation. Discrepancies were resolved by discussion.

Adopting Best Practices in DVT/PE Prophylaxis and Fluid Resuscitation in Critical Care

http://fluidsurveys.com/s/ECG_faciliatators_barriers_survey/

Informed Consent

This survey is to identify and evaluate barriers to, and facilitators of, best practices in:

1. Deep Vein Thrombosis (DVT) / Pulmonary Embolism (PE) prophylaxis for medical-surgical ICU patients, and
2. Fluid Resuscitation for medical-surgical ICU patients *without* liver disease, bacterial peritonitis, hepatorenal syndrome or therapeutic paracentesis.

This survey is not about trauma, neurosurgery or cardiac surgery patients. Survey responses will be used to develop interventions to facilitate the adoption of best practices in Alberta ICUs.

You are being asked to take part in this survey because you are a healthcare professional working in adult critical care in Alberta. Our survey can be answered in approximately **5 minutes**. There are no direct benefits and/or risks to your participation.

Survey respondents can choose to have their name entered into a draw for *$20 Starbucks gift cards* (one name will be drawn per week; non-winners will remain in the draw each week).

Your participation in this survey is voluntary and you are free to stop at any time. Your responses will be kept confidential. Your de-identified data will be stored in a password-protected database, and responses will only be presented in aggregate. The survey has peer-reviewed funding and has received ethics approval from the University of Calgary. **Your decision to complete and submit this survey will indicate your consent to participate.** Should you decide to withdraw your participation before submitting the survey, your data will be deleted.

If you have questions about this survey or your participation, please contact:
Rebecca Brundin-Mather, Research Coordinator, at brundin@ucalgary.ca.

If you have questions about your rights as a participant, you may contact the University of Calgary Conjoint Research Ethics Board at (403) 220-7990. This office is not affiliated with the study team.

Thank you in advance for taking the time to complete the survey!

Kind regards,

Tom Stelfox, MD, PhD, FRCPC
Intensive Care Physician
Scientific Director, AHS, Critical Care Strategic Clinical Network

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○ I agree to participate in this survey ○ I do **NOT** wish to participate in this survey (online-version)

Demographics

1. What is your professional group?

◯ ICU physician	◯ Nurse Clinician	◯ Pharmacist
◯ ICU resident	◯ Nurse Educator	◯ Other: _____
◯ ICU fellow	◯ Bedside Nurse	

2. Approximately how many years have you worked in:

Health care ☐ Critical care ☐

3. In which hospital(s) do you primarily work? (Select all that apply)

- ◯ Chinook Regional Hospital
- ◯ Foothills Medical Centre
- ◯ Grand Praire QE II Hospital
- ◯ Grey Nuns Hospital
- ◯ Medicine Hat Regional Hospital
- ◯ Misericordia Hospital
- ◯ Northern Lights Regional Health Centre
- ◯ Peter Lougheed Centre
- ◯ Red Deer Regional Hospital
- ◯ Rockyview General Hospital
- ◯ Royal Alexander Hospital
- ◯ South Health Campus
- ◯ Sturgeon Community Hospital
- ◯ University of Alberta Hospital

DVT/PE Prevention

We are interested in your perceptions of the different forms of prophylaxes commonly used to prevent Deep Vein Thrombosis (DVT) and Pulmonary Embolism (PE) in medical-surgical ICU patients (not trauma, neurosurgery or cardiac surgery patients). Common prophylaxes include:

- Low molecular weight heparin (**LMWH** e.g., Enoxaparin, Dalteparin, Tinzaparin)
- Unfractionated heparin (**UFH**, regular Heparin)
- **Mechanical** prophylaxis (i.e., sequential compression devices)

We appreciate that practices vary across units and providers. For each of the following questions, please select the **best response option** OR **options**, to the best of your knowledge (more than one response option can be selected).

4. Which form(s) of prophylaxis is/are most effective at preventing:

	LMWH	UFH	Mechanical	Unsure
Deep Vein Thrombosis (DVT)	☐	☐	☐	☐
Pulmonary Embolism (PE)	☐	☐	☐	☐

5. Which form(s) of prophylaxis is/are most cost-effective?

LMWH	UFH	Mechanical	Unsure
☐	☐	☐	☐

6. Which form(s) of *pharmacological* prophylaxis has/have the lowest risk of:

	LMWH	UFH	Unsure
Bleeding	☐	☐	☐
Heparin Induced Thrombocytopenia (HIT)	☐	☐	☐

7. To what extent do you think best practices for preventing DVT/PE are followed **in your ICU** (i.e., the patient receives the right prophylaxis with the right dose at the right time)?

○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ Unsure
Never			**Sometimes**			**Always**	

Intravenous Fluid Resuscitation

We are now interested in your perceptions of the different types of intravenous fluids commonly used for fluid resuscitation (i.e., fluid boluses) in the ICU for medical-surgical patients, **excluding** patients with liver disease, bacterial peritonitis, or undergoing therapeutic paracentesis as they may have different fluid needs. Common resuscitation fluids include:

- **Human Albumin** (Albumin 5% or Albumin 25%)
- **Crystalloid solutions** (e.g., normal saline, ringers lactate, and plasma-lyte)

Again, we appreciate that clinical practices vary across units and providers. For each of the following questions, please select the **best response option** OR **options**, to the best of your knowledge (more than one response option can be selected).

8. Which form(s) of IV resuscitation fluid is/are most effective for resuscitation?

Albumin ☐ Crystalloids ☐ Unsure ☐

9. Which form(s) of IV resuscitation fluid(s) is/are most cost-effective?

Albumin ☐ Crystalloids ☐ Unsure ☐

10. Which form(s) of IV resuscitation fluid(s) has/have the lowest risk of:

	Albumin	Crystalloids	Unsure
Fluid overload (peripheral / pulmonary)	☐	☐	☐
Contracting an infectious disease	☐	☐	☐

11. To what extent do you think *best practices* for prescribing fluid boluses are followed **in your ICU** (i.e., the patient receives the right fluid with the right dose at the right time)?

○	○	○	○	○	○	○	○
1	**2**	**3**	**4**	**5**	**6**	**7**	Unsure
Never			**Sometimes**			**Always**	

Barriers to Best Practices

A number of ICU or 'systems' factors have been identified as potential barriers to best practices. We are interested in what you think are barriers **in your ICU** to prescribing:

1. LMWH over UFH for DVT/PE prophylaxis
2. Crystalloid solutions over Albumin for fluid resuscitation

12. Which of the following factors are current barriers in your ICU to prescribing…

	LMWH over UFH		Crystalloids over Albumin	
	Current Barrier	Unsure	Current Barrier	Unsure
An ICU culture with an unclear or slow process for practice change	○	○	○	○
Not enough support from physicians	○	○	○	○
Not enough support from nurses	○	○	○	○
Not enough support from pharmacists	○	○	○	○
Clinical leaders in my ICU with strong clinical preferences	○	○	○	○
No clinical guidelines or orders sets in my ICU to guide the practice	○	○	○	○
Guidelines exist in my ICU, but they do not recommend LWMH over UFH / crystalloids over albumin	○	○	○	○
Insufficient knowledge/understanding the evidence base for the practice.	○	○	○	○
None of the above factors are current barriers in my ICU to prescribing….	○		○	
Please note any other factors that may be barriers to prescribing LMWH over UFH and/or crystalloids over albumin. Specify below.				

Strategies to Encourage Best Practices

A number of strategies have been identified as potential facilitators to changing clinical practice. We are interested in your perceptions of different strategies that have been used to encourage:

1. LMWH over UFH for DVT/PE prophylaxis
2. Crystalloid solutions over Albumin for fluid resuscitation

13. Which of the following strategies are currently used in your ICU to encourage…

	LMWH over UFH	Crystalloids over Albumin
1. On-site education (in-services, rounds, journal clubs, orientations)	○	○
2. Educational posters (in the unit)	○	○
3. Educational pocket cards	○	○
4. Email-based educational presentations	○	○
5. Web-based educational tools	○	○
6. Verbal reminders to physicians from pharmacists	○	○
7. Verbal reminders to physicians from bedside nurses	○	○
8. Pre-set orders	○	○
9. Computerized physician order entry & reminders	○	○
10. Web-based practice reminders	○	○
11. Daily goals checklist	○	○
12. Audit & feedback of prescription rates	○	○
13. A quality improvement team focusing on practice change	○	○
14. Participation in a quality improvement network	○	○
15. A local clinical leader championing the practice	○	○
16. Other strategy used. Please specify:	○	○
17. Other strategy used. Please specify:	○	○
NO strategies are currently being used in my ICU encourage this practice:	○	○

14. From the same list of strategies, please select the **5 best strategies** that you believe would work **in your ICU** to encourage:
    (1) LMWH over UFH for DVT/PE prophylaxis
    (2) Crystalloid solutions over Albumin for fluid resuscitation
    (Select up to **5 strategies**, regardless whether the strategy is used in your ICU or not)

Select up to 5 in each column

Strategy to change clinical practice	LMWH over UFH	Crystalloids over Albumin
1. On-site education (in-services, rounds, journal clubs, orientations)	☐	☐
2. Educational posters (in the unit)	☐	☐
3. Educational pocket cards	☐	☐
4. Email-based educational presentations	☐	☐
5. Web-based educational tools	☐	☐
6. Verbal reminders to physicians from pharmacists	☐	☐
7. Verbal reminders to physicians from bedside nurses	☐	☐
8. Pre-set orders	☐	☐
9. Computerized physician order entry & reminders	☐	☐
10. Web-based practice reminders	☐	☐
11. Daily goals checklist	☐	☐
12. Audit & feedback of prescription rates	☐	☐
13. A quality improvement team to focus on practice change	☐	☐
14. Participation in a quality improvement network	☐	☐
15. A local clinical leader to champion the practice	☐	☐
16. Other strategy. Please specify:	☐	☐
17. Other strategy. Please specify:	☐	☐

15. Finally, please provide any additional comments in the text box below.

Please select the check box(es) below to have your name entered in the Starbucks coffee card draws and/or to receive the study results.

☐ Yes, I would like my name entered in the coffee card draws.

☐ Yes, I would like to receive the results from this study.

My email address is:

N.B. E-mail addresses will be kept confidential and will not be used to contact you for any reason other than those noted above.

---End of Survey ---

Thank you for helping us improve care!

Please return completed surveys to:

Dr. Tom Stelfox
Department of Critical Care Medicine
Foothills Medical Centre

OR

Rebecca Brundin-Mather
Ward of the 21st Century
GD01 Teaching, Research, Wellness Bldg
University of Calgary, 3280 Hospital Dr NW
Calgary, AB T2N 4Z6

Supplemental Content 3. Intensive care unit patient characteristics for the study period (January 1, 2014-December 31, 2014)

Demographic variable	Population (N=6,946)	Adoption cohort 70.7% (N=4,931)	De-adoption cohort 93.1% (N=6,467)
Age, median (IQR)	60 (46-71)	61 (47-71)	61 (46-71)
Female	41.6 (2,888)	43.3 (2,134)	41.8 (2,703)
Comorbidities			
AIDS	0.6 (42)	0.7 (33)	0.5 (35)
Chronic dialysis	3.5 (240)	3.8 (186)	3.5 (225)
Chronic heart failure	6.4 (444)	7.4 (364)	6.5 (419)
Cirrhosis	5.9 (407)	6.0 (294)	0.0 (0)
Diabetes	19.7 (1,366)	21.6 (1,065)	19.9 (1,284)
Hepatic failure	3.9 (269)	4.1 (203)	0.0 (0)
Immune suppression	8.5 (589)	9.4 (463)	8.2 (532)
Leukemia or multiple myeloma	1.3 (88)	1.4 (69)	1.3 (86)
Lymphoma	1.1 (77)	1.2 (61)	1.2 (75)
Metastatic cancer	3.9 (272)	4.1 (203)	4.1 (262)
Respiratory insufficiency	12.0 (833)	14.6 (722)	12.5 (810)
Any comorbidity	44.6 (3,100)	49.3 (2,431)	40.6 (2,625)
Admitted from			
Emergency department	36.6 (2,540)	36.7 (1,808)	36.5 (2,358)
Operating / recovery room	21.9 (1,520)	18.3 (902)	22.2 (1,437)
Hospital ward	26.7 (1,858)	28.1 (1,386)	26.3 (1,702)
Other hospital	10.4 (722)	11.9 (589)	10.5 (677)
Other location	4.3 (300)	4.9 (243)	4.5 (288)
Unknown	0.1 (6)	0.1 (3)	0.1 (5)
Admission type			

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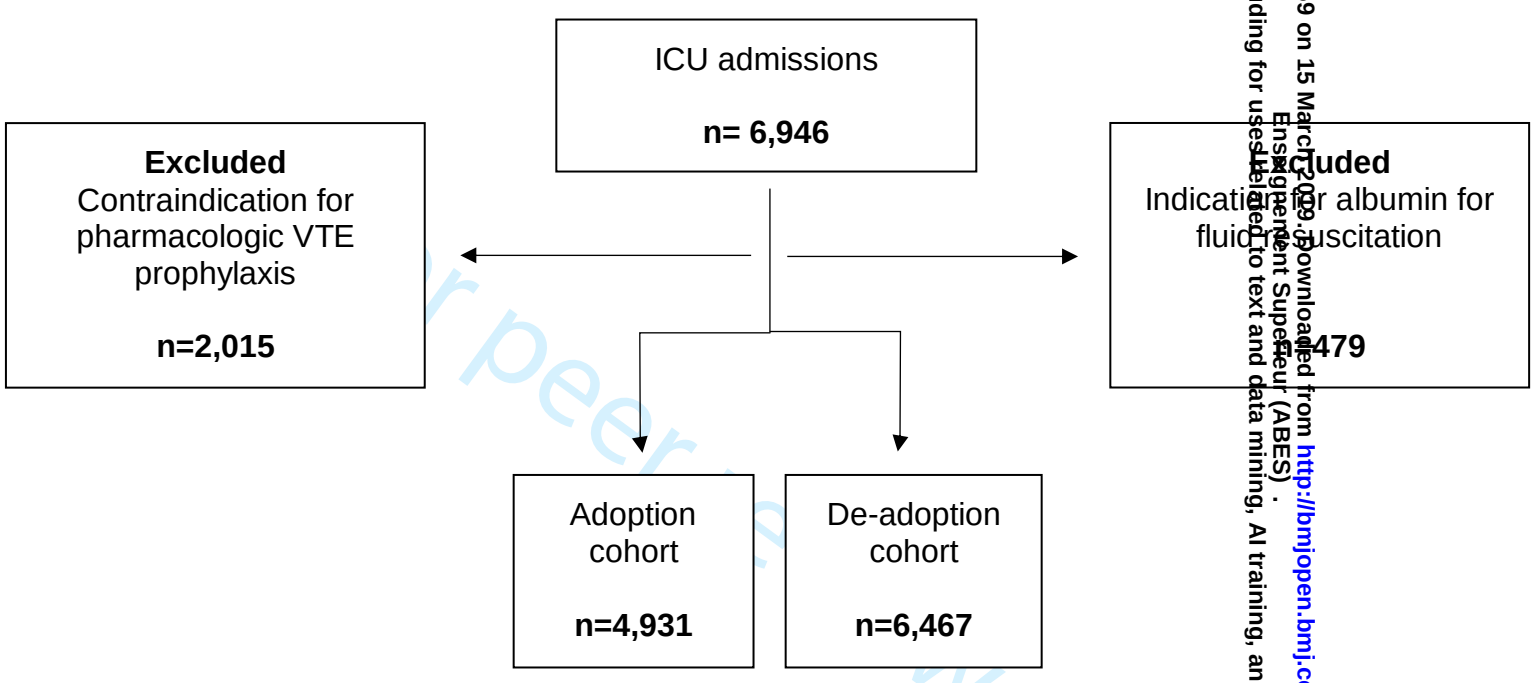
Elective surgery	9.4 (655)	8.1 (399)	9.5 (614)
Emergent surgery	16.8 (1,170)	13.8 (681)	17.3 (1,120)
No surgery	73.1 (5,078)	78.1 (3,851)	72.5 (4,690)
Unknown	0.6 (43)	0.0 (0)	0.7 (43)
Reason for ICU admission			
Medical	59.9 (4,163)	69.4 (3,420)	58.7 (3,797)
Surgical	25.8 (1,789)	24.1 (1,190)	26.2 (1,696)
Neurological	9.3 (649)	4.1 (200)	9.8 (632)
Trauma	4.3 (302)	2.5 (121)	4.6 (299)
Unknown	0.6 (43)	0.0 (0)	0.7 (43)
APACHE II Score on ICU admission, median (IQR)	19 (14-26)	20 (15-26)	19 (14-25)
Glasgow Coma Scale score on ICU admission, median (IQR)	14 (11-15)	14 (11-15)	14 (11-15)
Intubation	65.5 (4,553)	66.2 (3,264)	64.9 (4,195)
Invasive ventilation	68.3 (4,747)	68.8 (3,393)	67.8 (4,387)
Duration, median hours (IQR)	51 (18-133)	62 (25-143)	50 (18-132)
Non-invasive ventilation	13.1 (913)	16.2 (798)	13.6 (878)
Duration, median hours (IQR)	24 (8-63)	28 (9-68)	24 (6-65)
ICU length of stay, median days (IQR)	3.7 (1.8-7.7)	4.3 (2.4-8.3)	3.7 (1.8-7.6)
Hospital length of stay, median days (IQR)	13.3 (6.1-29.5)	13.9 (6.8-30.0)	13.2 (6.1-29.3)
ICU mortality	14.1 (981)	12.2 (601)	12.9 (837)
Hospital mortality	21.0 (1,462)	19.9 (979)	19.5 (1,260)

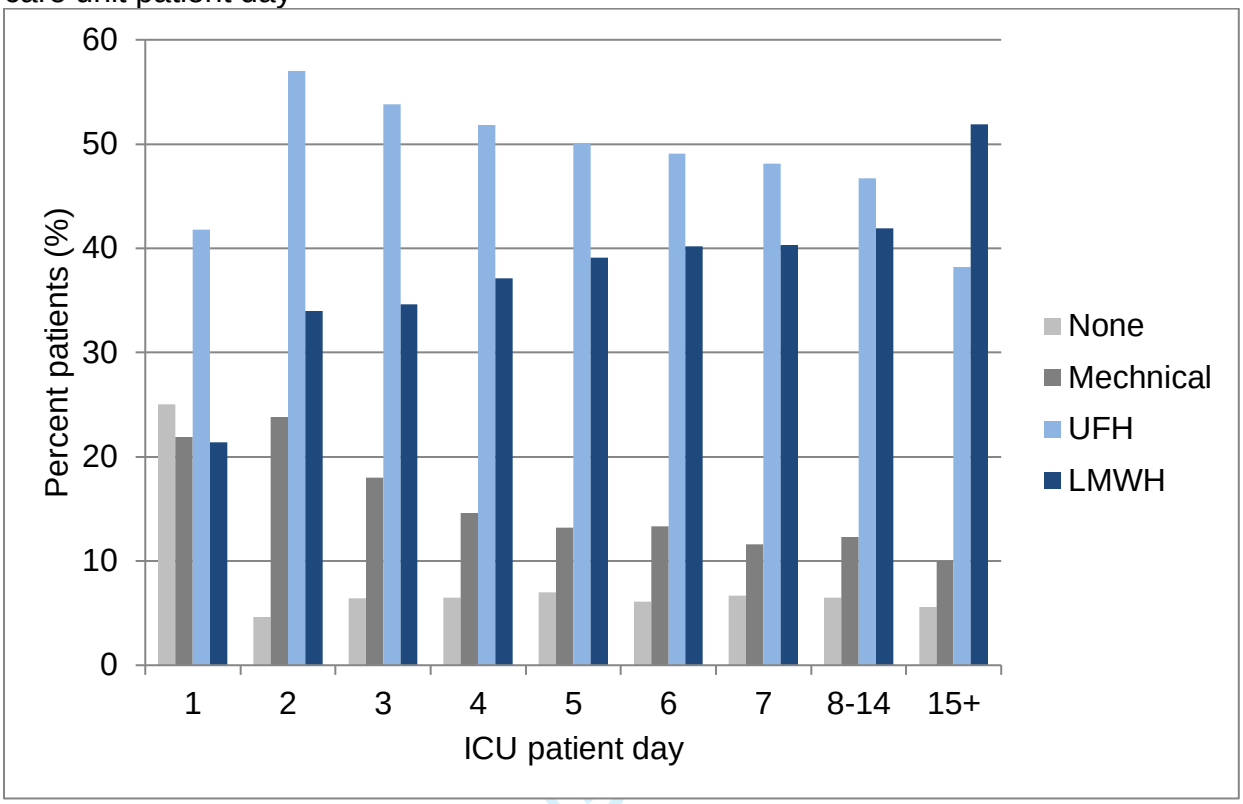
Abbreviations: **AIDS**=autoimmune deficiency syndrome, **APACHE II**=Acute Physiology and Chronic Health Evaluation II, **ICU**=intensive care unit, **IQR**=interquartile range,

Supplemental Content 4. Flow of patients



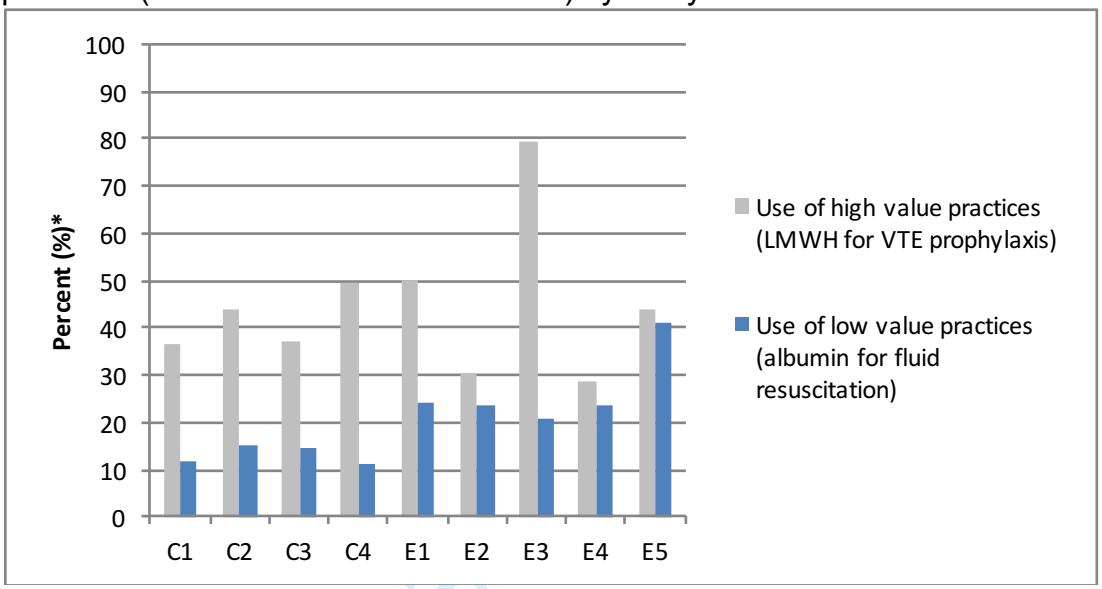
Footnote: Adoption cohort = Recommended to receive low molecular weight heparin for venous thromboembolism prophylaxis; de-adoption cohort = Recommended to NOT receive albumin for fluid resuscitation

Supplemental Content 5. Venous thromboembolism prophylaxis by intensive care unit patient day



Footnote: Percent of patients may add to greater than 100% because patients may have received more than one form of venous thromboembolism prophylaxis on a given patient day.
Abbreviation: ICU=intensive care unit, LMWH=low molecular weight heparin, UFH=unfractionated heparin

Supplemental Content 6. The use of high value practices (low molecular weight heparin for venous thromboembolism prophylaxis) and the use of low value practices (albumin for fluid resuscitation) by study intensive care unit



Footnote: all "C" sites indicate ICU in Calgary and all "E" sites indicate ICU in Edmonton

*% of patient-days for VTE prophylaxis and % of patients for albumin

Supplemental Content 7. Survey participant characteristics

Professional group	**% (N)**
Attending physician	24.7 (64)
Fellow	6.2 (16)
Resident	12.4 (32)
Nurse practitioner	5.0 (13)
Nurse manager / charge nurse	10.0 (26)
Nurse educator	8.5 (22)
Bedside nurse	23.9 (62)
Pharmacist	9.3 (24)
Years worked in ICU	Median (IQR)
Attending physician	14.0 (9.8-22.0)
Clinical fellow	1.8 (1.0-2.3)
Resident	0.3 (0.1-1.0)
Nurse practitioner	15.0 (9.0-20.0)
Nurse manager / charge nurse	11.5 (7.3-18.8)
Nurse educator	19.0 (10.3-21.5)
Bedside nurse	7.5 (2.5-12.0)
Pharmacist	5.3 (3.0-10.8)
Years worked in healthcare	Median (IQR)
Attending physician	19.0 (14.8-25.3)
Clinical fellow	8.0 (7.0-9.5)
Resident	3.0 (2.0-5.1)
Nurse practitioner	15.0 (12.0-25.0)
Nurse manager / charge nurse	16.5 (12.5-24.0)
Nurse educator	21.0 (13.0-26.0)
Bedside nurse	10.0 (6.0-16.0)
Pharmacist	10.5 (6.1-14.3)