A Smartphone-based Decision Support Tool Improves Test Performance Concerning Application of the Guidelines for Managing Regional Anesthesia in the Patient Receiving Antithrombotic or Thrombolytic Therapy

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ABSTRACT

Background: The American Society of Regional Anesthesia and Pain Medicine (ASRA) consensus statement on regional anesthesia in the patient receiving antithrombotic or thrombolytic therapy is the standard for evaluation and management of these patients. The authors hypothesized that an electronic decision support tool (eDST) would improve test performance compared with native physician behavior concerning the application of this guideline.

Methods: Anesthesiology trainees and faculty at 8 institutions participated in a prospective, randomized trial in which they completed a 20-question test involving clinical scenarios related to the ASRA guidelines. The eDST group completed the test using an iOS app programmed to contain decision logic and content of the ASRA guidelines. The control group completed the test by using any resource in addition to the app. A generalized linear mixed-effects model was used to examine the effect of the intervention.

Results: After obtaining institutional review board's approval and informed consent, 259 participants were enrolled and randomized (eDST = 122; control = 137). The mean score was 92.4 ± 6.6% in the eDST group and 68.0 ± 15.8% in the control group (P < 0.001). eDST use increased the odds of selecting correct answers (7.8; 95% CI, 5.7 to 10.7). Most control group participants (63%) used some cognitive aid during the test, and they scored higher than those who tested from memory alone (76 ± 15% *vs.* 57 ± 18%, P < 0.001). There was no difference in time to completion of the test (P = 0.15) and no effect of training level (P = 0.56).

Conclusions: eDST use improved application of the ASRA guidelines compared with the native clinician behavior in a testing environment. (ANESTHESIOLOGY 2016; 124:186-98)

WHY don't physicians follow clinical practice guidelines? This question was asked by Cabana *et al.*[1] 15 yr ago and continues to be a concern in health care today. The barriers to adherence to published clinical guidelines at that time were noted to be multifactorial, and numerous reports show that these barriers to adherence still exist, with poor adherence to guidelines being associated with poor patient outcomes and concerns for patient safety.[2–19] Recommendations concerning methods that might help mitigate barriers include the use of checklists and decision support systems.[20]

The 2010 American Society of Regional Anesthesia and Pain Medicine (ASRA) consensus statement on regional

What We Already Know about This Topic

- Adoption and correct application of evidence-based guidelines are often delayed and incomplete
- In other specialties, electronic decision support tools improve adherence to practice guidelines or protocols

What This Article Tells Us That Is New

- In this multicenter, randomized trial of more than 250 residents and faculty, use of an electronic decision support tool improved adherence to guidelines in a testing environment regarding regional anesthesia and anticoagulation compared with a control group who could freely access the guidelines and any other cognitive aid

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anesthesia in the patient receiving antithrombotic or thrombolytic therapy (hereafter referred to as ASRA guidelines) is the standard for the assessment of patients taking anticoagulant medications who need to be evaluated for the safety of placement and management of regional or neuraxial anesthesia blocks (epidural or spinal anesthesia).[21] Although these evidence-based guidelines are recognized as the standard for patient management, the complete document and executive summary are more than 40 pages long. Thus, it is likely that clinicians who perform procedures for regional or neuraxial anesthesia are unfamiliar with all of the details of the ASRA guidelines and that lack of adherence to these guidelines poses a problem for patient care and safety. On the basis of the previous work concerning a different major clinical guideline, we hypothesized that a smartphone-based electronic decision support tool (eDST) would improve test performance in the application of the ASRA consensus guidelines; test performance is not patient care, but it is a risk-free way of assessing knowledge of the guideline.[22] Accordingly, we performed a multicenter prospective randomized trial investigating the effects of an eDST on adherence to the ASRA guidelines concerning regional and neuraxial anesthesia for patients receiving anticoagulation compared with native physician behavior.

Materials and Methods

After obtaining institutional review board's approval (Nashville, Tennessee) and informed consent, anesthesiology residents, fellows, and faculty at 8 university-based institutions were recruited through email to participate in a prospective, randomized trial in which they completed a 20-question multiple-choice question (MCQ) test involving clinical scenarios related to the ASRA guidelines. The trial occurred from September to December 2013.

Knowledge Test Creation and Validation

The test creation process involved a modified Delphi technique that included anesthesiologists, educators, guideline experts, and faculty with training in medical board question writing from four participating institutions.[23–25] The construct of the test was assessed for content, response process, and internal structure validity.[26] The ASRA guidelines cover a range of medications known to affect coagulation and also the following four principal actions performed in regional or neuraxial anesthesia:

1. Performing the regional or neuaraxial anesthetic procedure
2. Restarting a medication after the procedure
3. Removing a neuraxial/perineural catheter while an anticoagulant is being administered
4. Restarting an anticoagulant medication after neuraxial/perineural catheter removal

In this test creation and evaluation process, each MCQ was mapped to a specific portion of the ASRA guidelines, and the questions were written such that each one tested a unique medication–action combination (validity source: representative of test items to knowledge domain and quality of test questions). Four faculty not involved with the test creation took the test and reviewed the answers in comparison to the ASRA guidelines to confirm that there was one clear best answer (validity source: quality of questions). Interitem correlation analysis was performed. Because the grading of the quiz was objective with a single correct answer for each question agreed upon by the group of faculty that evaluated the quiz, there was no reliability assessment of grading. The test was not used for participant assessment in any pass–fail manner, but rather in assessing the effect of the eDST as measured by correct responses to each question. The stems and MCQs can be reviewed in appendix 1.

Electronic Decision Support Tool Creation

The eDST (ASRA Coags©,* ASRA, USA) used in this study was programmed on the iOS platform and presented on the Apple iPod Touch (Apple, Inc., USA). A subset of the authors (M.D.M., W.R.H., R.G., J.M.C., and R.M.S.), in consultation with executive board members from ASRA, designed the logic of the eDST directly based on the ASRA guidelines. An iOS programmer created the code and executable application (Mustard Seed Software, USA). Various screenshots of the eDST can be seen in figure 1. Participants had no previous exposure to or formal training on use of the eDST before this study. The eDST was presented on iPod Touch or iPhone devices used specifically for this research project so that participants would not have access to the eDST before their testing session.

Study Design

Participants were randomly assigned to the eDST or control group through the use of a random number generator (see fig. 2). Demographic information was collected on participants, including training level, gender, and age, along with survey data concerning clinical experience, self-reported confidence in the application of the ASRA guidelines, and smartphone use. The eDST group was allowed to complete the test using the ASRA Coags© app (copyright 2014, Vanderbilt University and the ASRA). The control group was allowed to complete the test using any resource other than the eDST (*e.g.*, memory, internet, pocket cards). All participants were given access to an online video presentation after enrollment, which included a brief overview (approximately 10 min) of the ASRA guidelines and the format of the MCQ test. The eDST group was also shown an additional 5-min overview of the use of the app. Unlimited time was allowed

* The decision support tool described in this study was developed with intramural funds from Vanderbilt University Department of Anesthesiology and has since been marketed as an application on the Apple Store by the American Society of Regional Anesthesia as ASRA Coags©. Any fees collected on the sale of the application go to American Society of Regional Anesthesia and Pain Medicine for the maintenance and ongoing development of the application and to Vanderbilt for recuperation of development fees.

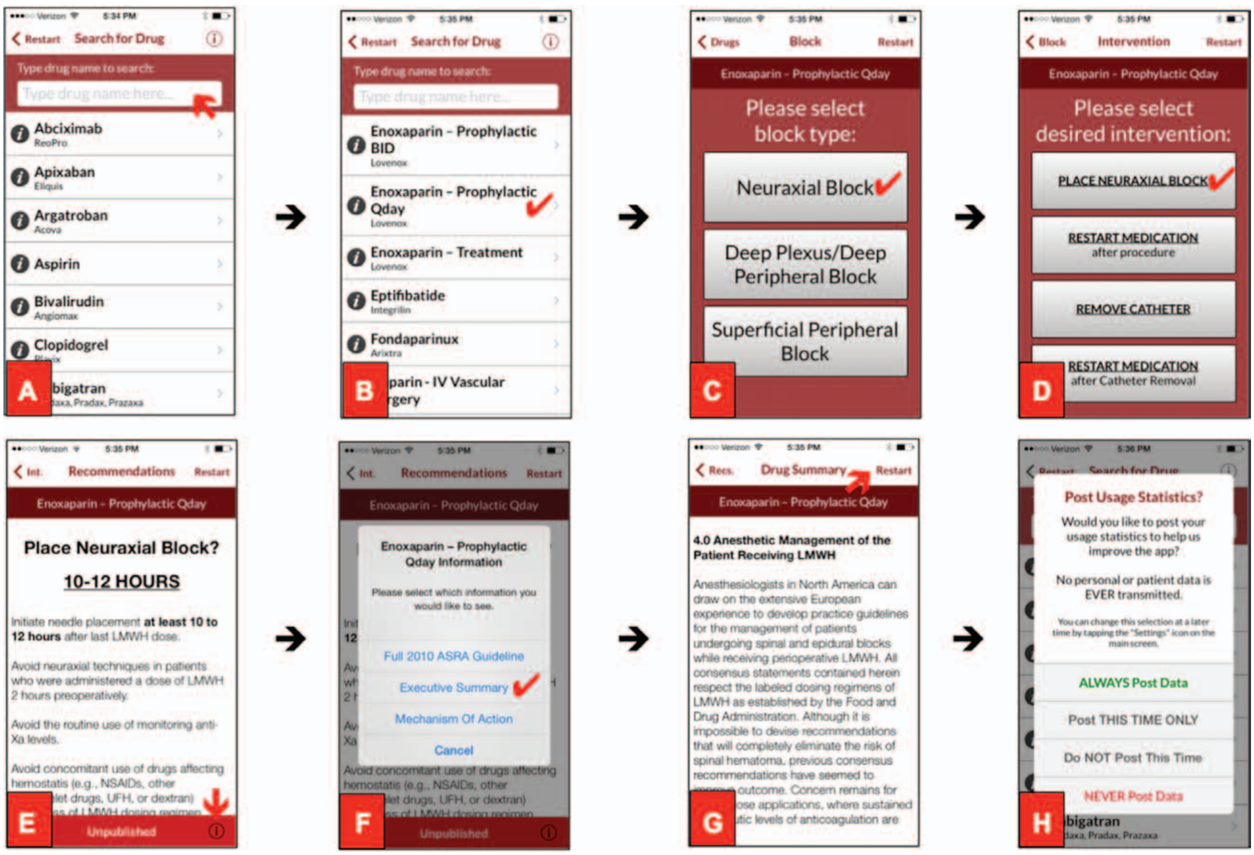

Fig. 1. This series of images displays screenshots that a user would encounter when navigating the electronic decision support tool (DST). After opening the application, the DST displays an alphabetized list of medications from the American Society of Regional Anesthesia and Pain Medicine (ASRA) guidelines along with a search functionality (*A*). After selecting medication and dosing schedule (click 1, *B*), the user is directed to select the type of block under consideration (click 2, *C*). In this example, "neuraxial block" is selected (*red check*), and the user is then presented with a choice of actions to perform (click 3, *D*). In this example, the user selects to place the block (*red check*), which directs the DST to present the conclusion of the ASRA guideline (*E*). Thus, in three clicks, the end user can arrive at the screen presenting the current ASRA guideline for that particular clinical situation. By clicking on the ⓘ button (*E*), the user is presented with choices for obtaining more information (*F*); in this example, this causes the executive summary for this block type, medication, dosing, and action to be presented (*G*). After the end user selects to return to the beginning (restart), or when the user navigates back to the home screen, he or she is given the opportunity to post this anonymous (non–protected health information) data to the ASRA Coags database (*H*).

for participant completion of the test, and time from start to completion was recorded.

Multisite compliance and logistics were regulated in the Department of Anesthesiology at Vanderbilt University. Randomization was implemented using computer-generated random numbers and was assigned in blocks of 100 to each site with 1 randomization block of 50 based on the training level of resident and 1 randomization of block of 50 for fellows/faculty. All participants were excused from active clinical duties and asked to silence all pagers and phones during the test. Testing of participants was accomplished within a 10-day period at each site, and all sites completed the study within a 4-month period. The programs that participated in the study were Vanderbilt University Medical Center (Nashville, Tennessee), Medical University of South Carolina (Charleston, South Carolina), University of Kentucky (Lexington, Kentucky), University of North Carolina (Chapel Hill, North Carolina), Ohio State University (Columbus, Ohio), Harvard University/Brighman and Women's Hospital (Boston, Massachusetts), University of Chicago (Chicago, Illinois), and Duke University (Durham, North Carolina). Participants were instructed to select the single best answer for each question. The answers given to each item were recorded into a REDCap database (REDCap, Vanderbilt University, USA).

Statistical Analyses

The responses to 20 MCQs were treated as binary outcomes (correct/incorrect). Because of feedback from test participants about the way in which question 17 was interpreted, two answers were considered correct for the analysis (see appendix 1). Of note, this did not affect the outcomes of the overall model. Recorded covariates included respondent demographics (age, gender), training level (residents: postgraduate year 1 to 4 and fellow; faculty: faculty and regional anesthesia faculty),

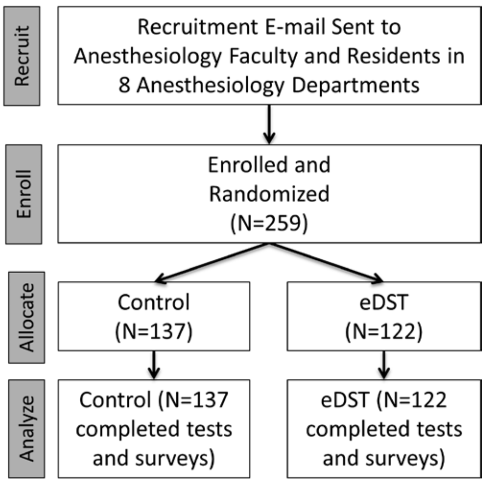

Fig. 2. This CONSORT diagram shows how participants were recruited, enrolled, allocated, and then analyzed. eDST = electronic decision support tool.

Table 1. Demographics

	Control (N = 137)	eDST (N = 122)
Age (yr)	36.2 (11.2)	34.7 (8.4)
Female	47 (34.3)	45 (36.9)
Level of training		
Intern (PGY-1 resident)	3 (2.2)	4 (3.3)
CA-1 (PGY-2 resident)	25 (18.2)	23 (18.9)
CA-2 (PGY-3 resident)	29 (21.2)	22 (18.0)
CA-3 (PGY-4 resident)	26 (19.0)	24 (19.7)
Fellow	2 (1.5)	5 (4.1)
Faculty	43 (31.4)	31 (25.4)
Regional Anesthesia Faculty	9 (6.6)	13 (10.7)
Training		
Resident	85 (62.0)	78 (63.9)
Faculty	52 (38.0)	44 (36.1)

There were no differences between groups for any comparison. Data are represented as n (%), except for age, which is represented as mean (SD).
CA = clinical anesthesia; eDST = electronic decision support tool; PGY = postgraduate year.

medication category (common: heparin, enoxaparin, warfarin, nonsteroidal antiinflammatory drugs and herbals; uncommon: others), and other practice characteristics. Participant demographics were summarized using the sample mean, SD, quartiles, and percentages, where appropriate, and stratified by control and intervention group. For the primary analysis, generalized linear mixed-effects regression model was used to examine the effect of intervention on the rate of correct responses, adjusting for age, gender, training level, and medication category. As a secondary analysis, we further examined the interaction between medication category and intervention and the interaction between question number and intervention. A random intercept was used to account for correlation among responses within respondent. Odds ratios (95% CIs) were used to quantify the adjusted effect of intervention, and that of each covariate, on the rate of correct response. Internal consistency of the test was assessed by using Cronbach α coefficient. Finally, a *post hoc* analysis was performed evaluating the performance of those in the control group who reported the use of some form of a cognitive aid and those who reported performance from memory alone.

Because no preliminary performance data were available for the study population, an *a priori* power analysis was not performed. The recruited sample size (eDST = 122; control = 137) provided 80% power to detect very subtle increases (~0.3 SD units) in the primary outcome, the proportion of correct responses attributable to the use of the eDST, assuming two-sided hypothesis testing and an α level of 0.05. All analyses were implemented using R 3.0.2 (R Foundation for Statistical Computing, Austria). Numerical values are presented as mean ± SD unless otherwise noted, and a significance level of 0.05 was used for statistical inference.

Results

After obtaining institutional review board's approval at all institutions and informed consent, a total of 259 participants were enrolled and randomized (control = 137; eDST = 122). Table 1 displays demographic information. The mean percent correct was 92.4 ± 6.6% in the eDST group and 68.0 ± 15.8% in the control group ($P < 0.001$, see fig. 3). The eDST group had a higher correct answer rate for all questions, and the adjusted odds of a correct answer was 7.8-fold greater in the eDST group, relative to control (95% CI, 5.7 to 10.7). Time required for test completion was not different between groups (control, 22 ± 9 min *vs.* eDST, 21 ± 8 min, $P = 0.15$). Because of an error with logging of the time function for some participants, 92% of participants had data available for analysis (N = 238/259; control = 122/137 and eDST = 116/122).

Table 2 shows the model-based effect estimates from the primary analysis (the effect of eDST intervention on the proportion of correct answers, adjusting for age, training level, and medication category). There was no evidence of training level (faculty *vs.* residents, $P = 0.56$) or medication type (common *vs.* uncommon, $P = 0.12$) effects, adjusting for intervention group and other covariates. There was a significant interaction between question number and intervention ($P < 0.001$). However, use of the eDST was associated with greater odds of correct response for all questions, relative to control, suggesting that the effect of intervention is to consistently improve the rate of correct response. Specifically, the effect of intervention was greatest for question 10 (odds ratio, 69.7; 95% CI, 7.8 to 620.5) and smallest for question 3 (odds ratio, 3.08; 95% CI, 0.5 to 18.9). This effect of the eDST was also true in the subset of regional anesthesia faculty, with the percent correct answers for regional faculty being 94 ± 5% for eDST and 77 ± 13% for control (N = 13 and = 9, respectively; $P < 0.001$). Thus, the control regional faculty (N = 9) scored on average 10% higher than all other control participants (67%). All data sets were complete with no ambiguity in answer selection or other potential sources

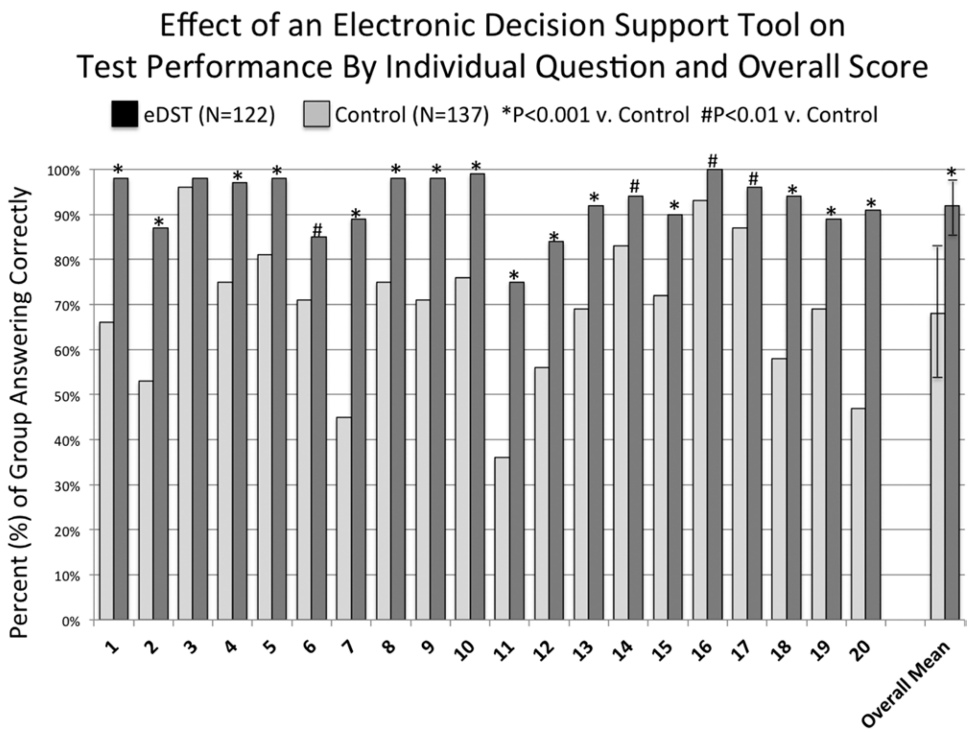

Fig. 3. This graph illustrates the effect of the electronic decision support tool (eDST) on performance compared with native behavior for each question and overall. The eDST significantly improved overall performance and performance for each question, except for question 3 where the scoring for both eDST and control was more than 95% correct. The *error bars* for the overall mean show the SD for each group across the entire test. Data are shown as mean ± 95% CI.

of error apparent to the authors. Cronbach α coefficients were calculated to be 0.85 ± 0.005, indicating a good level of internal consistency for each item and the test as a whole.

Of note, 63% of participants in the control group used some (one or more) form of a cognitive aid during the test (see table 3), with use of the ASRA website, other websites, and pocket cards being reported by 30.7, 24.1, and 18.2% of the control group, respectively. Of note, only 9.5% reported actually referencing the full ASRA consensus guideline publication, and a *post hoc* analysis was performed to assess for any effect of the use of a cognitive aid in this group. In the control group, those reporting that they used some form of a cognitive aid scored significantly better than those who performed from memory alone (76 ± 15% *vs.* 57 ± 18%, $P < 0.001$, respectively). When compared with both these groups (control + cognitive aid and control – memory alone), those in the eDST group performed significantly better ($P < 0.01$, see fig. 4).

In the pretest survey, the majority of respondents in both groups reported that the most frequently accessed reference that they referenced in the clinical setting being tested was a copy of the ASRA guidelines accessed through the Internet. Also, an overwhelming majority of participants reported feeling confident in their ability to apply the guidelines

Table 2. Effect of Covariates and Intervention on the Odds of Answering Correctly

Components Assessed in Multivariable Model	OR	CI	*P* Value
Participant age	0.99	0.97–1.01	0.144
Faculty	0.88	0.58–1.34	0.56
Uncommon medication	1.14	0.97–1.35	0.12
Intervention (eDST)	7.59	5.54–10.41	<0.001

This table displays an analysis of the recorded covariates in the generalized linear mixed-effects regression model. For the primary analysis, generalized linear mixed-effects regression was used to examine the effect of intervention on the rate of correct responses, adjusting for age, training level, and medication category, which is shown here as the average odds ratio of obtaining a correct answer when the covariate is considered as well as when the eDST was used.

eDST = electronic decision support tool; OR = odds ratio.

Table 3. Utilization of Reference Aid by Type in the Control Group (N = 137)

	Control, N (%)
Memory alone (no reference)	51 (37.2)
ASRA website	42 (30.7)
Other website	33 (24.1)
Smartphone App	6 (4.4)
Pocket card	25 (18.2)
ASRA publication	13 (9.5)
Other	3 (2.2)

This table details the use of reference aids by the control group, which should depict native behavior by physicians. Of note, approximately 63% of participants in this group used some reference aid when completing the test (86/137), with some participants reporting that they used more than one cognitive aid.

ASRA = American Society of Regional Anesthesia and Pain Medicine.

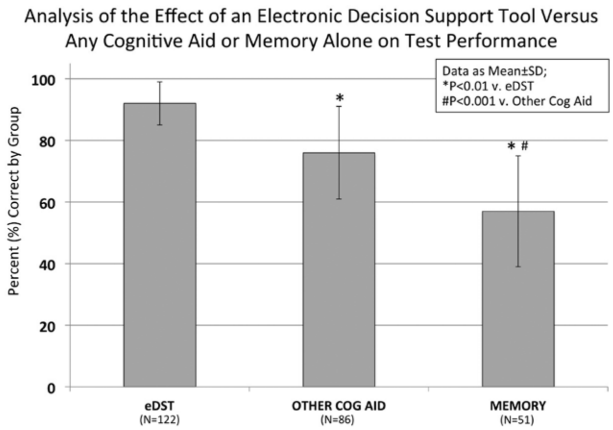

Fig. 4. This graph displays an analysis of the effect of an electronic decision support tool (eDST) *versus* any cognitive aid or memory alone on test performance, showing that the eDST still improved performance even after splitting the control group into those who used a cognitive aid and those who completed the test from memory alone.

concerning when to place a neuraxial block or remove a catheter relative to anticoagulant dosing (84 and 79%, respectively); and 62% of participants in the control group reported feeling confident that they could adhere to the ASRA guidelines concerning when to restart an anticoagulant after placing or removing a catheter. See appendices 2, 3, and 4 for complete details from the survey, including confidence in guideline application, data concerning familiarity with smartphones, and the frequency with which medical software or eDSTs are used by participants in a routine practice.

Discussion

Why don't physicians follow clinical practice guidelines? This has been asked for almost two decades, and it remains a problem today. It has been suggested that summary checklists and decision support tools (DSTs) might improve the correct application of consensus guidelines.[20] Accordingly, our study addressed whether an eDST designed to present the ASRA guidelines to physicians could improve performance in the application of guidelines in a variety of clinical scenarios presented as a MCQ test. Our group has recently shown that an eDST similar to the one in this study improves performance concerning the application of consensus guidelines for the preoperative cardiac evaluation of patients undergoing noncardiac surgery.[22] However, it should be noted that our previous study investigated the effects of the DST compared with the effects of memory alone, whereas in this study, we allowed participants in the control group to use any resource that they would normally use when managing a patient receiving regional or neuraxial anesthesia who was also getting anticoagulation. As such, our results advance upon those previous results and demonstrate four important findings.

First, the use of an eDST greatly improved performance compared with native physician behavior. Poor adherence to the ASRA guidelines concerning neuraxial blockade and anticoagulation has been demonstrated previously, thus highlighting the potential role for an eDST.[27] The electronic, smartphone-based DST tested in this study (ASRA Coags©) improved performance, as measured by MCQ test selections consistent with the ASRA guidelines, by an absolute 24% (36% relative) compared with performance with native physician behavior. In specific, the DST provided a statistically significant benefit for 19 of the 20 MCQ scenarios (see fig. 3), and this effect was equally present for common and uncommon medications (table 2). Of note, some cognitive aid was associated with better performance than memory alone, and the use of the eDST specifically tested in this study resulted in better performance than either memory alone or the use of other cognitive aids. This finding is significant because control group members were instructed to take the test using any aid or support tool that they would normally use during routine clinical practice. Thus, use of the eDST tested in this study resulted in performance superior to native physician behavior with or without a cognitive aid. Because the number of anticoagulant medications rapidly increases, our findings demonstrate a simple solution to an actual problem.[28,29]

Second, the effect of the eDST was not dependent on the training level. It would seem intuitive that physicians with more training and more years of practice experience would perform better than those who have yet to graduate from residency. However, we did not find any such effect across the study population. In a subgroup analysis, it was noted that control group Regional Anesthesia faculty scored 10% higher than others in the same group, but because of the sample size, this was not significant. Several previous studies have noted that clinicians at various levels of training and years of experience in practice showed no difference in performance in both crisis and noncrisis situations when managing the event from memory alone, with all groups performing poorly.[23,24,30–32] These reports, along with our study, speak to the fact that some facts may be best recalled and applied with the help of a cognitive aid.[33–37] Furthermore, this finding may highlight the particular areas of interest where the developers of guidelines and DSTs should work together to have a significant impact on healthcare delivery.[20]

Third, the positive effect of the eDST was generalizable across a wide range of institutions. Any time when a new DST is introduced, its efficacy and uptake will be determined by a number of factors, including the usability (design interface), clinician attitude toward the tool, and local culture. In addition, the general awareness of a guideline and clinician familiarity with the specific content can serve as a barrier to implementation.[1,20,38] Current recommendations encourage local modification of cognitive aids as needed to improve usability; mandating the use of such tools cannot guarantee its use or efficacy.[36,39] Rather, implementation is multifactorial, and local factors have been shown to be very important.[40,41] Our study did not specifically test the implementation of the eDST that we describe in a clinical setting. However, because usability is one major aspect of implementation of any DST, our finding of improved test performance of guidelines across a large number of institutions is noteworthy, particularly when 63% of participants in the control group reported using some form of decision support (*e.g.*, Internet, pocket card) during the study. That is, the control group used aids with which they were already familiar, whereas the intervention group used an aid that had just been introduced to them. Good usability of the DST is likely because of the fact that we performed an iterative design process for the user interface and decision logic during the programming of the app, seeking feedback from multiple sources, as described elsewhere.[42–44]

Fourth, self-reported confidence level in application of the guidelines being tested varied significantly from actual performance. Even though proper knowledge concerning the ASRA guidelines was demonstrated only 63% of the time by the control group, greater than 75% reported feeling confident in their ability to apply the guidelines concerning when to place a neuraxial block or remove a catheter relative to anticoagulant dosing (see table 2). Understanding the gap between reported familiarity with and actual application of the guidelines is important.

Taken together, these findings could have great import for future paradigms of education and practice of physicians and other healthcare providers.[33,45] Much literature is emerging about the need to embed a culture of safety and practice concerning checklists, DSTs, and other cognitive aids within medical education.[35–37] A number of pedagogical approaches have been recently shown to improve adherence to guidelines in a variety of settings, ranging from team training to electronic medical records with embedded DSTs.[46–50] We report on the effect of a DST deployed on mobile technology, a form increasingly used by clinicians and learners.[51–54] This form of active information retrieval and application in the workplace is something that our current trainees, who are digital natives, adept with these computer techniques, expect now and in future practice. Moving away from memorization and into information access and application is a strategy that can be ingrained in the training of clinicians and one that will possibly improve the use of guidelines.[55] Future studies will need to address this question, and physicians will need to work with national organizations to produce DSTs that can guide safe patient management, as we have done with the ASRA since the creation of this DST as an iOS application.

At this point, two particular limitations of this study should be noted. First, this study reports the effect of a DST on knowledge of guidelines in a structured testing condition rather than clinical practice. Second, the tool did not lead to perfect performance, and there was some variability in the degree of improvement in the rate of correct responses across the 20 tested scenarios (*i.e.*, an intervention-by-scenario interaction). The latter may be because of limitations in the validity of the testing construct, or to other, more nuanced factors. Concerning testing construct, one source of validation is the fact that control group Regional Anesthesia faculty scored higher than other control group participants by 10%. There are also a variety of reasons in cognitive processing/decision-making that explain why physicians do not use decision support even when it is available. This is most common when physicians (mistakenly) believe that they recognize a clinical situation or recall a fact correctly. It is not human nature to regularly verify that which we already believe to be correct unless there has been significant training to do so, such as forced closed loop communication in the airline or military industries. We suggest that what this finding really means, rather than lack of validity of the test or procedure, is that human factors engineering is an important part of decision support and that simply providing a tool with the ability to reach the correct answer is insufficient to prevent error with 100% certainty. Future research can address both of these limitations by exploring the effect of this DST in actual clinical practice or at least with *in situ* simulation replicating clinical encounters.

Conclusions

In summary, use of the eDST significantly improved scores on a test of knowledge of the ASRA guidelines for simulated scenarios of patients being evaluated for regional anesthesia who are taking anticoagulant medications. Because all clinicians should attempt to practice evidence-based medicine, and because an increasing percentage of the population is taking an expanding number of anticoagulant medications, these results indicate that it may be time to embrace decision support technology for such patients undergoing neuaraxial or regional anesthesia. Future research needs to address the implementation of such tools in the clinical setting.

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Competing Interests

For completeness, Drs. McEvoy and Hand have received funding from Edwards Life Sciences (Irvine, CA) for research completely unrelated to this project. The other authors declare no competing interests.

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Appendix 1: Multiple-choice Test

Participant ID: __________

Please select the **SINGLE BEST** answer in line with the American Society of Regional Anesthesia and Pain Medicine (ASRA) Management Guidelines for Neuraxial and Regional Anesthesia in the Patient Receiving Antithrombotic or Thrombolytic Therapy

1. A 42-yr-old otherwise healthy, white woman with uterine cancer is presenting for a total abdominal hysterectomy. You have planned to place a low-thoracic epidural for postoperative pain control. She received heparin 5,000 units subcutaneously 30 min ago, and orders are written for this dose every 12 h. She is on no other medications. How long should you wait before placement of the epidural?

    A) 1 h after last dose
    B) 2 h after last dose
    C) 4 h after last dose
    D) **No contraindication to placing epidural immediately [C]**†

2. A 68-yr-old Hispanic man is postoperative day 2 from thoracotomy for left-sided bleb resection. He has sudden new onset of neurologic symptoms and is diagnosed with acute ischemic stroke followed by alteplase administration. The pain service is contacted by the covering nurse practitioner because he thought there may be an issue with the patient's thoracic epidural. What is the best course of action?

    A) Continue current therapy
    B) Discontinue epidural catheter immediately
    C) Recommend neurologic monitoring every 3 h
    D) **No definitive recommendation. Check fibrinogen level to help guide timing of catheter removal [U]**

3. A 57-yr-old African American woman is on warfarin for atrial fibrillation and is scheduled for a colectomy for diverticulitis. Her international normalized ratio (INR) in clinic 2 weeks before scheduled surgery date is 2.9. The surgeon would like her to receive a thoracic epidural and asks about how to counsel her regarding her warfarin. Which of the following is the best course of action?

    A) Hold for 3 days and check for normalized INR on day of surgery to ensure it is less than 1.8.
    B) **Hold for 5 days and check for normalized INR on day of surgery to ensure it is less than 1.5 [C].**
    C) Hold for 7 days and proceed with epidural.
    D) Hold night before surgery and check INR on day of surgery to ensure it is less than 1.5.

† [C] or [U] was not included on the test when given. This notation is to show how the question was included in the covariate analysis of common [C] *versus* [U] medications. Also, the correct answer is in bold, but this was in standard font when the test was given.

4. A thoracic epidural is placed preoperatively without complication for an open abdominal aorta aneurysm repair in a 72-yr-old white man. How long before systemic heparinization (intravenous unfractionated heparin) can be given after placement of the epidural?

    A) Minimum of 30 min
    B) **Minimum of 1 h [C]**
    C) Minimum of 2 h
    D) Minimum of 3 h

5. A 66-yr-old white man presents on the morning of surgery for a total hip arthroplasty, and you plan to place a lumbar plexus catheter. He had a drug-eluting stent placed 12 months ago. He had intolerable side effects from clopidogrel and prasugrel and has thus been receiving ticlopidine for antiplatelet therapy. How long should he be off his ticlopidine before placement of the block?

    A) 3 days
    B) 7 days
    C) **14 days [U]**
    D) 21 days

6. A 74-yr-old African American man comes to the postanesthesia care unit with a lumbar epidural after a large lower extremity free-flap plastic surgery procedure. The plan is to leave the epidural in place for 3 to 4 days. When performing postoperative pain rounds, you notice an order for 40 mg enoxaparin subcutaneously every 24 h. What do you do?

    A) **Give first dose of enoxaparin 8 h postoperatively and second dose at least 24 h later. Epidural catheter can be safely maintained [C].**
    B) Discuss safety concern of this dosing regimen with surgical team and recommend 30 mg enoxaparin subcutaneously every 12 h instead.
    C) Give first dose of enoxaparin 4 h postoperatively and second dose 24 h later. Epidural catheter can be safely maintained.
    D) For safety reasons with this dosing regimen, remove epidural immediately and wait 12 h for enoxaparin dosing.

7. A 65-yr-old white man with coronary artery disease and history of drug-eluting right coronary artery stent placement 12 months ago presents for exploratory laparotomy for colorectal carcinoma resection. He stopped his clopidogrel 6 days ago. An epidural is planned for postoperative pain control. Which of the following is the proper management?

    A) Postpone the case until the patient has been off clopidogrel for 10 days.
    B) Proceed with case as patient has been off clopidogrel for more than 5 days.
    C) **As patient has been off clopidogrel 5 to 7 days, delay surgery to assess whether platelet function is normal [C].**
    D) Postpone the case until the patient has been off clopidogrel for 14 days.

8. A 78-yr-old white man with history of systolic heart failure (ejection fraction 27% on recent echocardiogram), uncontrolled diabetes, and multiple deep vein thromboses presents for placement of intertrochanteric screw after a right hip fracture yesterday. He has a history of heparin-induced thrombocytopenia after treatment for a pulmonary embolus a year ago. He was placed on argatroban for deep vein thrombosis prophylaxis last night and is presenting for surgery this morning. He requests a spinal for his anesthesia. What is the guideline recommendation concerning placement of a spinal for this patient?

   A) **Neuraxial technique is not recommended [U]**
   B) Wait for 2 h after last dose
   C) Wait for 12 h after last dose
   D) Wait for 24 h after last dose

9. A 58-yr-old white woman with known history of heparin-induced thrombocytopenia takes fondaparinux because of a concomitant diagnosis of atrial fibrillation. She had a partial pancreatectomy after appropriate cessation of anticoagulation in which a high thoracic epidural catheter was placed. How long after placement of the catheter is it safe to restart fondaparinux?

   A) Wait for at least 2 h after placement
   B) Wait for at least 6 h after placement
   C) **Fondaparinux is not recommended for patients with indwelling catheters [U]**
   D) Wait at least 24 h after placement

10. A 57-yr-old Asian man presents for bilateral total knee replacements on consecutive days. The surgeon has requested an epidural be placed and remain in place through the second surgery. Your preoperative interview reveals the patient takes ginkgo biloba and garlic supplements for prophylactic anticoagulation because of an aspirin allergy. He has taken these herbal supplements on the day of surgery. How long after taking these supplements can he have an epidural safely placed?

   A) Wait for 2 h after taking garlic
   B) Wait for 6 h after taking ginkgo biloba
   C) **Proceed immediately as there is no significantly increased risk of hematoma [C]**
   D) Wait for 4 half-lives before placing neuraxial block

11. A 23-yr-old African American woman with Factor V Leiden deficiency had a scheduled repeat cesarean section to orchestrate the timing of her anticoagulation. The case was performed under epidural because of the possibility of adhesions and extended duration. Normal coagulation was confirmed before the epidural placement. You are now in the recovery area after an uncomplicated surgical delivery, and you have just removed her epidural catheter. She has had a pulmonary embolism previously and thus is very anxious to restart her anticoagulation. How long until she may be safely dosed with prophylactic 30 mg enoxaparin subcutaneously twice daily?

   A) Restart immediately as her risk of deep vein thrombosis and pulmonary embolism is very high
   B) Wait a minimum of 4 h after catheter removal for the first dose of low-molecular-weight heparin (LMWH)
   C) **Wait a minimum of 24 h after surgery for the first dose of LMWH [C]**
   D) Wait a minimum of 6 h after surgery for the first dose of LMWH

12. A 55-yr-old African American male patient with infected total knee arthroplasty presents preoperatively for arthrotomy and hardware removal. Twelve hours ago, he required angioplasty and was started on eptifibatide until he can have definitive cardiac therapy after having his infected joint removed. The cardiologist stated that it was okay to hold the eptifibatide for surgery and that he would recommend avoiding general anesthesia for the case to avoid hemodynamic stress on his heart. The patient is also exceedingly anxious about general anesthesia and requests spinal anesthesia. As such, the case will be performed under subarachnoid block. How long should eptifibatide be held before performing the block?

   A) Wait for at least 2 h
   B) **Wait for 4 to 8 h [U]**
   C) Wait for 12 h
   D) Subarachnoid block not recommended for patient on eptifibatide

13. A 66-yr-old white man is admitted with necrotizing pancreatitis. The patient had a pulmonary embolism earlier in this hospitalization that has resolved. He was started on 30 mg enoxaparin subcutaneously twice daily. Pancreatic debridement is scheduled for tomorrow, and the anesthetic plan includes a thoracic epidural for postoperative pain control. How long should the anesthesiologist wait to place the epidural after the last preoperative enoxaparin dose?

   A) Wait for at least 2 h
   B) Wait for at least 6 h
   C) **Wait for at least 10 to 12 h [C]**
   D) Neuraxial block is not recommended for patients on LMWH twice daily

14. A 71-yr-old white woman with a prosthetic aortic valve presents for a left total hip arthroplasty. Anesthesia is planned with lumbar plexus catheter. Her warfarin was held for 5 days. When can you safely place lumbar plexus catheter?

   A) The patient has been off warfarin long enough (5 days); proceed with block
   B) Wait for at least 7 days and recheck international normalized ratio (INR)
   C) **Proceed with block if INR has normalized [C]**
   D) Proceed with block if INR is less than 2.0

15. A 72-yr-old Hispanic man is postoperative day 3 after a total knee replacement and has had excellent postoperative pain control with a lumbar epidural catheter. He is receiving 40 mg enoxaparin subcutaneously once daily. How long should you wait after administration of enoxaparin to remove the epidural catheter?

A) 1 h
B) 2 h
C) **10 to 12 h [C]**
D) 1 h before the next scheduled dose of enoxaparin

16. A 25-yr-old otherwise healthy Asian woman athlete scheduled for knee reconstructive surgery desires to be awake during the procedure. Her only medication is ibuprofen and she took 800 mg orally 12 h before surgery. The most appropriate action would be:

A) Measure platelet function before any neuraxial technique is performed
B) Wait for at least 3 half-lives of ibuprofen before performing neuraxial technique
C) Proceed and perform spinal anesthesia but do not perform epidural anesthesia
D) **Proceed with spinal or epidural anesthesia [C]**

17. An orthopedic surgeon wants to use prophylactic daily doses of dalteparin subcutaneously for thromboprophylaxis after a hip replacement procedure. A continuous epidural catheter is used during the procedure in a 52-yr-old Indian man and is left in place overnight for pain control. When should the epidural catheter be removed in relation to dalteparin dosing?

A) **At least 2 h before the first dose [U]**
B) At least 2 h after the first dose
C) **At least 12 h after the last dose**
D) At least 12 h after the last dose and after checking prothrombin time and partial thromboplastin time

18. A 76-yr-old white man with peripheral vascular disease underwent femoral popliteal bypass with epidural anesthesia. The epidural was placed on the first attempt without complication. Postoperatively, the epidural catheter was removed after an appropriate time period after the last dose of systemic heparinization. How long must you wait until intravenous heparin can be safely restarted?

A) **1 h [C]**
B) 2 h
C) 4 h
D) 12 h

19. A 48-yr-old Asian woman with colon cancer underwent colectomy 2 days ago. An epidural catheter that was placed preoperatively has provided excellent pain management but was just now removed. Enoxaparin 40 mg subcutaneously once daily has been used for deep vein thrombosis prophylaxis in the postoperative period. How long should you wait after epidural catheter removal to restart enoxaparin?

A) May restart immediately
B) **Minimum of 2 h [C]**
C) Minimum of 4 h
D) Minimum of 10 h

20. A 44-yr-old African American woman who is receiving unfractionated heparin (5,000 units subcutaneously twice daily) for deep vein thrombosis prophylaxis after total abdominal hysterectomy has a continuous epidural catheter in place and the surgeon asks that it be removed. The nurse just administered 5,000 units subcutaneously unfractionated heparin. How long should you wait before removing the catheter?

A) **Catheter can be removed immediately [C]**
B) 2 h
C) 4 h
D) 12 h

Appendix 2: Number of Neuraxial and Regional Blocks Performed

	Control (N = 137)	eDST (N = 122)
Approximately how many neuraxial blocks (epidurals and subarachnoid blocks) have you performed?		
0–25	22 (16.1)	26 (21.3)
26–50	14 (10.2)	10 (8.2)
51–100	22 (16.1)	17 (13.9)
101–150	17 (12.4)	15 (12.3)
> 150	62 (45.3)	54 (44.3)
Approximately how many peripheral nerve blocks have you performed (including brachial and lumbar plexus)?		
0–25	41 (29.9)	34 (27.9)
26–50	32 (23.4)	18 (14.8)
51–100	21 (15.3)	23 (18.9)
101–150	14 (10.2)	19 (15.6)

Data are represented as n (%).
eDST = electronic decision support tool.

Appendix 3: Use of References and Confidence in Practice Concerning ASRA Guidelines

	Control (N = 137)	eDST (N = 122)
When presented with a patient on antithrombotic or thrombolytic therapy who is a potential candidate for neuraxial blockade, what reference do you utilize most frequently during preoperative evaluation to determine whether the patient is an appropriate candidate for block?		
Supervising faculty direction	28 (20.4)	25 (20.5)
ASRA guidelines accessed on the web	74 (54.0)	68 (55.7)
ASRA guidelines in hard copy	17 (12.4)	11 (9.0)
Personal knowledge of ASRA guidelines	18 (13.1)	18 (14.8)
How often do you refer to the ASRA guidelines for regional or neuraxial anesthesia when evaluating patients for neuraxial blockade who are receiving antithrombotic or thrombolytic therapy?		
Very frequently	31 (22.6)	18 (14.8)
Frequently	45 (32.8)	33 (27.0)
Occasionally	33 (24.1)	43 (35.2)
Rarely	20 (14.6)	21 (17.2)
Never	8 (5.8)	7 (5.7)
I am confident in my ability to appropriately apply the ASRA guidelines in the patient receiving antithrombotic or thrombolytic therapy in the following conditions:		
When to place a neuraxial block		
Strongly disagree	5 (3.6)	4 (3.3)
Disagree	8 (5.8)	7 (5.7)
Undecided	9 (6.6)	16 (13.1)
Agree	72 (52.6)	70 (57.4)
Strongly agree	43 (31.4)	25 (20.5)
When to remove a catheter		
Strongly disagree	2 (1.5)	2 (1.6)
Disagree	9 (6.6)	15 (12.3)
Undecided	18 (13.1)	21 (17.2)
Agree	75 (54.7)	65 (53.3)
Strongly agree	33 (24.1)	19 (15.6)
When to restart antithrombotic medication after placing catheter		
Strongly disagree	3 (2.2)	1 (0.8)
Disagree	12 (8.8)	22 (18.0)
Undecided	37 (27.0)	34 (27.9)
Agree	65 (47.4)	55 (45.1)
Strongly agree	20 (14.6)	10 (8.2)
When to restart antithrombotic medication after removing catheter		
Strongly disagree	3 (2.2)	1 (0.8)
Disagree	16 (11.7)	25 (20.5)
Undecided	33 (24.1)	30 (24.6)
Agree	62 (45.3)	55 (45.1)
Strongly agree	23 (16.8)	11 (9.0)

Data are represented as n (%).

ASRA = American Society of Regional Anesthesia and Pain Medicine; eDST = electronic decision support tool.

Appendix 4: Smartphone Familiarity and Frequency of Smartphone Use

	Control (N = 137)	eDST (N = 122)
How familiar are you with the use of a "smartphone" or "smart device"?		
Never used one before	2 (1.5)	0 (0.0)
Some limited experience	9 (6.6)	7 (5.8)
Very familiar with its use	126 (92.0)	114 (94.2)
How often do you use medical software or electronic cognitive aids on a smart phone or iPod?		
Never	18 (13.1)	14 (11.5)
Monthly	19 (13.9)	22 (18.0)
Weekly	40 (29.2)	35 (28.7)
Daily or almost daily	60 (43.8)	51 (41.8)

Data are represented as n (%).

eDST = electronic decision support tool.