Influence of improved teaching on medical students’ acquisition and retention of drug administration skills


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Background. Drug administration error is a major problem causing substantial morbidity and mortality worldwide. Lack of education about drug administration appears to be a causative factor. We devised an online teaching module for medical students and assessed its short- and long-term efficacy.

Methods. One hundred and thirty clinical medical students were invited to undertake additional, online, teaching about drug administration. Those participating were identified and the number of web pages viewed recorded. The students’ knowledge retention was tested by means of drug administration questions incorporated into routine assessments and examinations over the next 6 months. Other indices of all students’ performance were recorded to correct for confounding factors.

Results. Just over half (52%) responded to the invitation to participate. The amount of interest they showed in the teaching module correlated positively with their performance in questions about drug administration, although the latter waned over time. Surprisingly, correcting for students’ general ability and keenness revealed that the less able students were most likely to undertake the teaching module.

Conclusions. Additional online teaching about drug administration improves students’ knowledge of the topic but clearly requires reinforcement; however, only about half the students took up the option. Medical students must acquire these fundamental skills, and online teaching can help. Medical educators must ensure that drug administration is taught formally to all students as part of the curriculum and must understand that it may require additional teaching.

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Introduction

There is substantial evidence that doctors have difficulty calculating drug doses correctly,1 although the extent to which this contributes to the global problem of clinical error and iatrogenic harm is unclear. Our previous research,2,3 and that of others,4 has focused upon problems caused by expressing the concentration of drug solutions as ratios and percentages. In 2004, we surveyed doctors’ understanding of drug concentrations in brief clinical scenarios.3 Almost 15% were unaware that a 1:1000 solution of epinephrine contains 1 mg ml−1 and >33% could not identify the mass of lidocaine in 10 ml of a 1% solution. More would have given the correct volumes in ensuing clinical scenarios, appearing to know ‘approximately the right amount’ to give based on the volume in one ampoule. This is not a sound basis for avoiding dose errors, particularly with children, where small volumes are needed. We also found that only 65.5% would have administered the correct volume of atropine, possibly because of difficulties with a microgram to milligram conversion in the calculation. Clearer labels and better education are evidently necessary.

In 2003, the General Medical Council of the UK made recommendations on undergraduate medical education that specify that students should learn the ‘Effective and safe use of medicines (side-effects, interactions, antibiotic resistance, genetic factors)’ and be able to ‘Work out...
drug-dosage and record the outcome accurately.\cite{5} The acquisition of drug administration skills is mentioned in our medical school curriculum. We recently found out how much our students struggle with dose calculations\cite{2} and believe formal teaching of the topic was completely overlooked. We have incorporated a formal drug administration teaching session into the anaesthesia attachment but note that students often seem to be expected to acquire these practical skills on an *ad hoc* basis during the course: clearly many miss out.

There is evidence that students benefit from additional practical training sessions in drug administration given by a pharmacist.\cite{6} Although we acknowledge that virtual reality is not necessarily the best way of teaching clinical skills, we wished to assess the impact of an online module designed to teach the basics and arithmetic of drug administration.

**Methods**

We invited all 130 final-year medical students in our university to participate in additional, online, drug administration teaching during the anaesthesia and perioperative medicine attachment (http://erweb.cbcu.cam.ac.uk/drug-dosage/?$=G) by means of our web-based teaching system.\cite{7} We recorded respondents’ identities and the number of web pages of the teaching material they viewed. We incorporated the six multiple choice questions (MCQs) from Figure 1 into the negatively marked anaesthesia examination taken 2 weeks later and recorded all students’ answers. To assess the retention of information, we recorded students’ marks in different drug administration questions in the objective structured clinical examination (OSCE) part of the final examination 6 months later and their overall performance in the anaesthesia, OSCE, and final examinations. As a result of negative and close marking schemes, the probability of giving a correct answer was calculated for each student to allow later statistical modelling. Data were analysed using Statview (SAS Institute, Cary, NC) and statistical modelling performed with R (http://www.r-project.org).\cite{8} Further statistical analyses of the data were performed using modelling through binomial distributions and logistic regressions. The protocol was approved by our local ethics and research committees.

**Results**

Sixty-eight students (52%) responded, viewing on average 39 web pages each (range 1–187, median 26, interquartile range 69). The marking structures and students’ results in each of the examinations are shown in Table 1. In Figure 2 these are divided into quartile groups based upon the number of web pages of the module viewed. The positive relationship between the probability of students’ success in the six drug administration questions and the number of web pages viewed (Fig. 3A) suggested that the teaching was beneficial in the short term ($P=0.0013$). A negative relationship between the numbers of web pages viewed and the scores in the rest of the anaesthesia examination (Fig. 3B) and overall marks in Finals showed that the more successful students were *less* likely to have viewed the teaching material. A logistic model fitted with both number of web page visits and the scores in the rest of the MCQ examination as independent variables, which more accurately reflects the situation expected if the students had been randomized to reduce the influence of performance bias, revealed an increase in the magnitude of the coefficient for the number of web pages viewed [0.011 ($P=0.0001$) in the logistic bivariate model vs $0.0091$ ($P=0.0013$) in the previously fitted logistic univariate model].

The logistic fittings constructed to examine the influence of the coefficients for web pages viewed and/or surrogates of ability on performance in the drug administration elements of the OSCE 6 months later showed that the students were generally less successful in these questions. Comparison of the coefficients in the log odds scale (0.0034 for the OSCE vs 0.0091 for the anaesthesia examination) suggested that the benefit of the teaching is reduced by two-thirds by the time of the OSCE.

**Discussion**

After correcting for potential confounding factors, the positive correlation between students’ performance in drug administration questions and the number of web pages viewed suggests that our online teaching material had a positive influence on their knowledge of drug administration that waned over time.

A potential criticism of this study is that the students were invited to participate in additional teaching rather than randomized. We corrected for the possible confounding factor of keener students being more likely to undertake the teaching by using their overall examination marks as indices of general ability and were surprised to find that the *less* academic students spent more time on the teaching and gained most benefit from it. There are several arguments in favour of this approach. First, in our experience medical students are notoriously competitive and worry constantly about their performance in assessments and examinations. They can be very resourceful and frequently share information about teaching and learning. We are confident that many of those randomized not to view the additional teaching would have managed to do so. Second, by incorporating drug administration questions into later examinations, we were able to assess long-term retention of information. These examinations are integral to students’ progress through medical school and randomization would have put half the students at a disadvantage. In this way, the study was conducted without alerting the students to our interest in their long-term knowledge of drug dose calculation. Inevitably, most students would have revised the topic had they known, introducing a major confounding factor.

We believe that this design more accurately reflects the realities of teaching medical students, was more equitable
and yielded data that could not have been obtained within the constraints of a rigid randomized trial. For example, a randomized trial would not have shown that only about half of students are likely to participate in voluntary online teaching. One disadvantage was that the statistical analysis was much more complex.

Our previous study showed students’ poor understanding of parenteral drug administration, with knowledge

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**Q1:** The first picture shows an ampoule of epinephrine. It contains 1 ml of 1 in 1000 epinephrine. How much epinephrine is there in the ampoule?

A. 10 µg  
B. 100 µg  
C. 10 mg  
D. 1 mg (Correct)  
E. 1000 mg

**Q2:** You are treating a 10-year-old whom you suspect is in anaphylactic shock. The protocol says the recommended intramuscular dose of epinephrine is 250 µg. What volume of solution in the picture will you give?

A. 2.5 ml  
B. 0.25 ml (Correct)  
C. 0.025 ml  
D. 2.5 µl  
E. 25 µl

**Q3:** The second picture shows an ampoule of lidocaine. It contains 10 ml of 1% w/v lidocaine. How much lidocaine is there in the ampoule?

A. 100 µg  
B. 10 g  
C. 10 mg  
D. 100 mg (Correct)  
E. 1000 mg

**Q4:** You find yourself treating a 60 kg patient with a laceration that you will need to suture under local anaesthetic. Given that the maximal safe dose of lidocaine is 3 mg kg\(^{-1}\), what is the maximum volume of the solution in the picture that can be administered safely?

A. 60 ml  
B. 6 ml  
C. 180 ml  
D. 18 ml (Correct)  
E. 180 µl

**Q5:** Here is a Mini-Jet™ of atropine as found on emergency drugs trolleys. There is 1 mg in 10 ml. What is the concentration of the solution?

A. 1 mg ml\(^{-1}\)  
B. 10 µg ml\(^{-1}\)  
C. 0.1 mg ml\(^{-1}\) (Correct)  
D. 1 µg ml\(^{-1}\)  
E. 0.1 µg ml\(^{-1}\)

**Q6:** At work, you come across a patient with an acute symptomatic bradycardia. A pulse is present and the blood pressure is 85 mm Hg systolic. You estimate their weight is 60 kg. You choose to treat this with atropine at 20 µg kg\(^{-1}\). How much of this solution will you need to give?

A. 12 ml (Correct)  
B. 1.2 ml  
C. 6 ml  
D. 8.5 ml  
E. 0.6 ml

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**Fig 1** The six questions about drug administration from the anaesthesia examination (correct answers marked). Adapted from the work of Wheeler and colleagues.\(^5\)
seemingly absorbed by osmosis rather than as a consequence of formal teaching. As the clinical pharmacology curriculum evolves to encompass cell and molecular biology, drug administration might be neglected. This study shows that an online teaching module can improve some students’ drug administration knowledge, but that the offer of additional teaching is taken up only by roughly half. For topics of which students tend to lack knowledge or which

Table 1 A summary of marks obtained by students in drug administration questions and overall examinations and an explanation of the format of each examination. MCQ, multiple choice question; OSCE, objective structured clinical examination

<table>
<thead>
<tr>
<th>Examination Type</th>
<th>Mean Score</th>
<th>Median Score</th>
<th>Range</th>
<th>Interquartile Range</th>
<th>Examination Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drug administration MCQs in anaesthesia examination</td>
<td>3.95</td>
<td>4</td>
<td>−4 to +6</td>
<td>4</td>
<td>Negatively marked MCQs</td>
</tr>
<tr>
<td>Anaesthesia examination overall</td>
<td>66.7%</td>
<td>68.0%</td>
<td>31–90%</td>
<td>17.0%</td>
<td>Negatively marked MCQs</td>
</tr>
<tr>
<td>OSCE intravenous drug administration</td>
<td>80.2%</td>
<td>82.5%</td>
<td>35–100%</td>
<td>20.0%</td>
<td>OSCE. Mark out of 20 converted to percentage</td>
</tr>
<tr>
<td>OSCE dose calculation</td>
<td>77.9%</td>
<td>90.0%</td>
<td>0–100%</td>
<td>45.0%</td>
<td>OSCE. Mark out of 15 converted to percentage</td>
</tr>
<tr>
<td>OSCE overall</td>
<td>84.7%</td>
<td>85.0%</td>
<td>55.0–94.0%</td>
<td>6.0%</td>
<td>OSCE. Accumulated percentage scores at 20 stations</td>
</tr>
<tr>
<td>Finals overall</td>
<td>182</td>
<td>182</td>
<td>176–191</td>
<td>5.5</td>
<td>Close marked written, oral and clinical</td>
</tr>
</tbody>
</table>

Fig 2 Graphs to show the students’ scores (A) in the drug administration questions of the end-of-attachment perioperative medicine MCQ; (B) overall in the end-of-attachment perioperative medicine MCQ; (C) in the drug administration questions of the OSCE; (D) in the final examinations. Students were divided into quartiles by the number of web pages viewed, shown on the x-axis. Error bars are 95% confidence intervals. For further statistical analysis see Results.  

Medical students, education and drug error
tend to be overlooked, online teaching can complement classroom teaching. Drug administration skills may seem basic or mundane, but it is vital for patient safety that they are properly taught and reinforced at medical school. Doctors working in all clinical disciplines involved in drug application should collaborate to teach and reinforce these skills throughout medical school so that the knowledge may be retained better. The arithmetic involved in drug dose calculation is simple and all medical students and doctors should be capable of answering our six questions correctly. The fact that they cannot reflect the human tendency to make errors, and consideration should once again be given to improving drug labelling.

For topics that can be overlooked, online teaching may be able to plug gaps in students’ knowledge. However, online modules must be engaging, useful and educational—rather than lecture notes simply transferred to a web page—to ensure that students are motivated to access them. The vast amount of information available on the Internet can also be overwhelming; students may require guidance and learning portfolios can be helpful in this regard. The methodology described in this study could be used to audit their efficacy as well as conduct research.

Acknowledgement
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