Point-of-care testing for patients with diabetes, hyperlipidaemia or coagulation disorders in the general practice setting: a systematic review

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Background. Point-of-care testing (PoCT) is increasingly being used in the general practice setting and has the potential to provide improved health outcomes for patients.

Objectives. The aim of the study was to systematically assess the literature relating to the analytical performance, clinical effectiveness, cost and satisfaction of patients and health professionals with PoCT for monitoring patients with diabetes, with hyperlipidaemia or requiring anticoagulant therapy in general practice.

Methods. Systematic review and synthesis of randomized and quasi-randomized trials during 1966–2007 was performed. PubMed, EMBASE, CINAHL, Current Contents, BIDS and the Cochrane Library databases were searched using key terms relating to PoCT for diabetes (glycosylated haemoglobin, urine albumin creatinine ratio), hyperlipidaemia (total cholesterol, triglycerides and high-density lipoprotein) and anticoagulant therapy (international normalized ratio) in the general practice setting.

Results. Nine papers from six randomized or quasi-randomized trials were included in the review. Large between-study heterogeneity made pooling of the data inappropriate. In terms of clinical effectiveness, no study found a significant difference between PoCT and pathology laboratory testing. There was a similar lack of data in relation to the analytical performance of PoCT, to cost outcomes and to patient and health professional satisfaction, making conclusions difficult to infer.

Conclusions. This systematic review does not provide robust evidence that PoCT in general practice improves patient health outcomes, that it has comparable analytical quality to pathology laboratory testing, that it is cost-effective compared to usual care or that patients and health professionals find PoCT satisfactory. The number of trials is low, the follow-up of patients is short and many of the trials did not investigate PoCT as a separate intervention.

Keywords. Anticoagulant therapy, diabetes, general practice, hyperlipidaemia, point-of-care testing.

Introduction

Point-of-care testing (PoCT) is defined as any test taken by or on behalf of the treating doctor on-site at the time of consultation that allows the test result to be used to make immediate decisions about patient treatment.\textsuperscript{1} PoCT is sometimes referred to as near-patient testing or bedside testing. Many laboratory tests such as the testing of glucose in urine were first developed at the bedside and in effect PoCT pre-dated the concept of the centralized laboratory as we now know it today. Recently, there has been a trend back to performing tests at the bedside or at least closer to the patient.

The growing interest in PoCT has come about partly through technological advances that have enabled smaller and simpler analytical devices to be manufactured. However, there are also clinical reasons why the use of PoCT is growing around the world particularly in primary care. Hobbs et al.\textsuperscript{2} cite a number of challenges that face the primary care physician such as intolerance of a late diagnosis, an increasing need
to filter access to specialist care, the earlier discharge of patients from hospitals and demands to manage the monitoring of chronic disease. It can be appreciated that PoCT might offer assistance with meeting all these challenges.

In 1997, Hobbs et al. published the first major systematic review of PoCT in primary care. They concluded that there was little evidence to support the general introduction of PoCT in general practice in preference to laboratory services. Yet, it was suggested that PoCT could provide value to patients particularly in monitoring of chronic disease. The review found that in general the quality of the methods reported in the literature was poor and that issues such as patient acceptability and patient outcomes were not adequately addressed. There was also little published on the cost-effectiveness of PoCT in general practice. Overall, it was suggested that further research in the primary care setting was required to determine whether PoCT would be valuable. They also recommended that future systematic reviews should be focused, subject specific and include all aspects of PoCT such as analytical performance, effectiveness and stakeholder satisfaction.

Since the systematic review by Hobbs et al. in vitro, diagnostics industry statistics show that PoCT has grown substantially both in volume and in terms of the types of available tests. In addition, there have been numerous publications in the peer-reviewed literature relating to PoCT. Given that 10 years have elapsed since the Hobbs et al. review, it appears timely to review the PoCT literature relating to the use of PoCT in general practice and in particular to systematically assess the evidence for this type of testing for the management of established chronic conditions. This systematic review was conducted in parallel to a larger randomized controlled trial (RCT) that was performed to inform policy decisions relating to the implementation of PoCT for monitoring patients with either type 1 or type 2 diabetes and hyperlipidaemia and patients requiring anticoagulant therapy in an Australian general practice setting.

Methods

Literature search
The medical literature was searched to identify relevant studies for the period between 1966 and 2007. The databases searched included PubMed, EMBASE, CINAHL, Current Contents, BIDS and the Cochrane Library. The electronic database search terms for all databases included MeSH terms and text words concerning the intervention (PoCT), condition (diabetes, hyperlipidaemia and anticoagulant therapy), test [glycosylated haemoglobin (HbA1c), urine albumin creatinine ratio, total cholesterol, triglycerides, high-density lipoprotein and international normalized ratio (INR) or prothrombin time] and setting (general practice) (Table 1 can be found in the supplementary material online). In addition, the reference lists of all articles included in the review were appraised to identify any studies that were not detected through the electronic searches. Primary investigators of identified trials were contacted for details of any unpublished studies or studies currently taking place in PoCT for diabetes, anticoagulant therapy or hyperlipidaemia in a general practice setting in the last 12 months.

One author was electronically sent monthly updates from PubMed (December 2006—November 2007) for any new articles for the search terms used in the electronic database search. An additional hand search was conducted for the period January 2007–November 2007 of four key journals: British Medical Journal, Clinical Chemistry, Journal of Near Patient Testing and Technology and British Journal of General Practice. The systematic review of Hobbs et al. and the Point-of-Care Testing book edited by Price et al. was also hand searched for potentially missed articles.

Study selection
Types of participants and setting. Studies of adults > 18 years treated for diabetes, hyperlipidaemia or receiving anticoagulant therapy in a general practice setting in either an urban or rural geographic location were included.

Types of intervention. The intervention was defined as PoCT and studies were included in the review when PoCT was compared in a randomized or quasi-randomized trial to usual care that was defined as testing in a conventional pathology laboratory setting.

Types of outcomes. Outcome measures included:
1. Analytical performance as indicated by a comparison of the accuracy and precision of PoCT to the equivalent laboratory test.
2. Clinical effectiveness as indicated by improvements in patient health outcomes (e.g. significant improvement of the number of patients in the therapeutic range) or change in patient management as a result of the immediate information provided by PoCT.
3. Cost.
4. Patient satisfaction and acceptability.
5. Health professional (GP, PoCT device operator) satisfaction and acceptability.

Types of studies. All study designs irrespective of any language restrictions were included in the search but letters, reviews, commentaries, conference abstracts and editorials were excluded.
Selection of studies. We selected studies for inclusion in the review if they were randomized or quasi-randomized in design. All titles and abstracts were independently assessed by two review authors to determine which articles should be included in the systematic review.

Data extraction and management. Two review authors independently extracted data from the articles onto a paper data collection form based on the tools developed by the Critical Appraisal Skills Programme.7 The data collection forms were piloted prior to use to ensure applicability.

Assessment of methodological quality. All trials were assessed independently by two review authors with discrepancies being resolved by discussion. We assessed the methods and reporting of each of the studies for bias (selection bias, performance bias, attrition bias and detection bias), internal/external validity and relevance. Face-to-face meetings were held to discuss extracted information and confirm the inclusion of each article. An assessment of the studies was completed by categorizing them into low risk of bias (met all the above criteria), moderate risk of bias (one or more criteria moderately met) or high risk of bias (one or more criteria not met).

Data synthesis. The data were summarized from the studies in text and table format, before providing a descriptive synthesis of findings.

Results

Search results
The electronic database searches retrieved 2043 papers of which 64 were identified as potentially appropriate for inclusion in the review. Three potentially relevant papers were identified through the PubMed monthly electronic database search updates and a further 10 were identified after screening through the reference lists of the previous 64 papers and Hobbs et al.2 systematic review. Of these 77 papers, nine met the criteria and were considered appropriate to be included in the review (see Fig. 1). Of the nine papers, one was included from three studies identified from the monthly electronic database search and one paper was included from the screening of reference lists. A possible explanation for this latter study6 not being identified in the original database search could be that key criteria such as PoCT, near-patient testing or the general practice setting were not included in the title or abstract of the article.

The search terms used in the review were broad to ensure that a comprehensive body of relevant literature was obtained. However, most papers were excluded because in most cases the term ‘point-of-care’ was being used for diagnostic purposes or for conditions and health settings not included in the review.

None of the nine papers met all the methodological criteria and were categorized as having moderate risk of bias.

Characteristics of included studies
A total of nine papers6–14 were generated from six trials. Three of the trials investigated INR PoCT,7–11 two investigated diabetes PoCT12–14 and one hyperlipidaemia PoCT.9 Four of the trials investigated PoCT with another intervention.7–11,14 The geographical setting included the UK (n = 5),7,10–13 USA (n = 2)6,14 and Belgium (n = 2).8,9 A detailed table summarizing the trials included in the review can be found in Table 1.

PoCT and analytical performance
Only one trial assessed the analytical performance of PoCT. This was a randomized crossover trial7 that investigated the agreement of INR PoCT compared to pathology laboratory testing and found that PoCT overestimated the INR result compared to the laboratory method. However, Bland–Altman plots showed that the agreement between PoCT and laboratory results was clinically acceptable.

PoCT and clinical effectiveness
All six trials reported clinical effectiveness as an outcome measure with some reporting more than one outcome. Two of the trials measured differences between groups,7,12 three investigated both between-and within-group differences8,10,14 and two determined the impact of a PoCT result on clinical decisions.6,14

Shiach et al.7 who investigated between-group differences showed no significant improvement in the PoCT group compared to the control group in terms of the time spent in the INR target range. Claes et al.8 and Fitzmaurice et al.10 measured both between- and within-group differences and found a significant improvement in the INR PoCT group at the end of study (within-group analysis) but no significant differences were found between the intervention and control groups.

Two trials12,14 investigated the clinical effectiveness of diabetes PoCT. Both Khunti et al.12 and Miller et al.14 showed no significant difference in the HbA1c value in the intervention compared to the control groups but Miller et al.14 who investigated within-group differences demonstrated an improvement in the mean HbA1c value. Miller et al.14 also investigated the impact of PoCT on clinical decisions and found that the general practice significantly intensified diabetes therapy in the PoCT group compared to the control group.

One trial investigated the clinical effectiveness of hyperlipidaemia and PoCT. Ruffin et al.6 examined
the impact of PoCT on clinical decisions and found that PoCT made a significant impact on clinical decisions with more coronary heart disease interventions in the PoCT group compared to the control group.

**PoCT and cost**
Three trials investigated PoCT and cost outcomes. There were two trials of INR PoCT and cost with both undertaking a cost-effectiveness analysis from a health care provider perspective. Claes et al. found that PoCT provided net savings for the health care provider while Parry et al. found PoCT costs to be greater than usual care. The RCT of Khunti et al. measured the total cost for diabetes-related care and found no statistical differences between PoCT and usual care.

**PoCT and patient satisfaction**
Only two trials assessed patient satisfaction with PoCT. Shiach et al. reported that patients were satisfied with INR PoCT but no statistical analyses were performed. Stone et al. investigated diabetes PoCT and patient satisfaction and found no significant difference between the intervention and control group.

**PoCT and health professional satisfaction**
One trial investigated health professional satisfaction with PoCT and this was for diabetes. Stone et al. reported on diabetes PoCT and health professional satisfaction; however, no statistical analyses were performed as this was a qualitative assessment of satisfaction. Results showed that GPs were concerned about the cost of equipment and consumables but nurses found the devices easy to use and cited the benefits of an immediate result for discussion with the patient.

**Discussion**

**Key findings**
Despite the increase in the use of PoCT since the publication more than a decade ago of the last systematic review of PoCT in general practice, there remains...
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<tr>
<th>Author, reference</th>
<th>Study design</th>
<th>Intervention</th>
<th>Condition</th>
<th>Population</th>
<th>Outcomes</th>
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<tr>
<td>Shiach et al(^7)</td>
<td>Randomized crossover trial</td>
<td>PoCT, computer decision support</td>
<td>Anticoagulant therapy</td>
<td>46 patients, age and gender not reported</td>
<td>Clinical effectiveness (between-group differences), patient satisfaction, safety</td>
<td>INR, CoaguChek</td>
<td>12 months</td>
<td>No difference in time spent in INR target range between groups (60.9% PoCT versus 59.3% laboratory); patients had greater satisfaction with PoCT; Bland–Altman plot showed that the INR difference increased as the average INR increased; no significant difference between geometric mean INR with PoCT and laboratory systems (2.48 versus 2.50, ( P = 0.08 )); INR values &gt;4.0 were less reliable; no difference in the dependability of the two INR systems</td>
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<td>Claes et al(^8)</td>
<td>RCT</td>
<td>Four interventions: education, education + feedback, education + PoCT, education + computer decision support</td>
<td>Anticoagulant therapy</td>
<td>834 patients, mean age = 70.2 years, 455 males, 379 females</td>
<td>Clinical effectiveness (between- and within-group differences)</td>
<td>INR, CoaguChek</td>
<td>12 months (6 months retrospective and 6 months prospective)</td>
<td>All four interventions resulted in significant increase in percent time spent within 0.5 INR from target (49.5% at baseline to 60% after intervention); no difference in percent in target range or event rates between different interventions</td>
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<tr>
<td>Claes et al(^9)</td>
<td>RCT</td>
<td>Four interventions: education, education + feedback, education + PoCT, education + computer decision support</td>
<td>Anticoagulant therapy</td>
<td>834 patients; data used from a larger trial(^5); of 66 practices, 16 general practice interviews, five persons involved in the organization of study interviewed, age and gender not reported</td>
<td>Cost-effectiveness</td>
<td>INR, CoaguChek</td>
<td>12 months (6 months retrospective and 6 months prospective)</td>
<td>PoCT + education resulted in net savings and quality improvement. The cost per test was reduced to €14.13 and accounted for €36.74 per patient per month; the incremental cost-effectiveness ratio for education + PoCT were dominant over usual care. In a sensitivity analysis, when overhead costs were varied, the dominance of this intervention versus usual care was lost (at an overhead cost of €8 instead of €10.05)</td>
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<td>Fitzmaurice et al&lt;sup&gt;10&lt;/sup&gt;</td>
<td>RCT</td>
<td>PoCT, computer decision support</td>
<td>Anticoagulant therapy</td>
<td>224 patients, age not reported, 55% male and 45% female</td>
<td>Clinical effectiveness (between- and within-group differences)</td>
<td>INR, Thrombotrak</td>
<td>12 months</td>
<td>No difference in level of control of INR (point prevalence) between groups; PoCT group had an improvement in the proportion of time in INR range (as did all groups) but not significantly different from the control practices</td>
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<td>Parry et al&lt;sup&gt;11&lt;/sup&gt;</td>
<td>RCT</td>
<td>PoCT, computer decision support</td>
<td>Anticoagulant therapy</td>
<td>224 patients, data used from a larger trial,&lt;sup&gt;10&lt;/sup&gt; age = 67 years, intervention versus 68 control, 45% female versus 42%</td>
<td>Cost-effectiveness</td>
<td>INR, Thrombotrak</td>
<td>12 months</td>
<td>Cost of PoCT was £170 (95% CI £149–190) versus £69 (95% CI = £57–81) in primary care (&lt;i&gt;P&lt;/i&gt; &lt; 0.01); sensitivity analysis indicated that cost of PoCT could be reduced to &lt;£100</td>
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<td>Khunti et al&lt;sup&gt;12&lt;/sup&gt;</td>
<td>Prospective RCT</td>
<td>PoCT</td>
<td>Type 2 diabetes</td>
<td>681 patients (319 intervention and 319 control), age = 65.7 years, 57% males versus 59%</td>
<td>Clinical effectiveness (between-group differences), costs</td>
<td>HbA1c, Bayer DCA 2000</td>
<td>12 months</td>
<td>Proportion of patients with HbA1C &lt;7.0% not statistically different between two groups; difference in cost of care in two groups not statistically different</td>
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<td>Stone et al&lt;sup&gt;13&lt;/sup&gt;</td>
<td>Prospective RCT</td>
<td>PoCT</td>
<td>Type 2 diabetes</td>
<td>410 patients, 11 staff interviews, 15 patient interviews, age and gender not reported, participants part of larger trial&lt;sup&gt;12&lt;/sup&gt;</td>
<td>Patient satisfaction, general practice and device operator satisfaction</td>
<td>HbA1c, Bayer DCA 2000</td>
<td>12 months</td>
<td>No increase in patient satisfaction in PoCT group; interviews showed that nurses found equipment easy to use; GPs saw the cost of equipment and consumables as a disadvantage; usefulness of having an immediate result differed between practices (reflecting the manner PoCT in which PoCT was set up and the nurse’s level of responsibility for making management changes)</td>
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<td>Miller et al&lt;sup&gt;14&lt;/sup&gt;</td>
<td>Prospective controlled trial (quasi-randomized)</td>
<td>PoCT, general practice education review: diabetes before start of study</td>
<td>Type 2 diabetes</td>
<td>597 patients (317 intervention and 280 control), age = 61 years, 78.8% female versus 78.6%</td>
<td>Clinical effectiveness (between- and within-group differences and impact on clinical decisions)</td>
<td>HbA1c, Bayer DCA 2000</td>
<td>188 days</td>
<td>PoCT led to more intensification of therapy in patients with HbA1C &gt;7.0 at baseline (51 versus 32, &lt;i&gt;P&lt;/i&gt; = 0.01), more so when HbA1C &gt;8.0; in PoCT group, HbA1C fell from 8.4% to 8.1% (&lt;i&gt;P&lt;/i&gt; = 0.04) but not in routine group—8.1–8.0 (&lt;i&gt;P&lt;/i&gt; = 0.31); no statistically significant changes in HbA1c between groups</td>
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a dearth of well-designed studies to determine the outcomes from this type of testing. Thus, the overwhelming conclusion now remains the same as that of Hobbs et al., namely, there is insufficient evidence to support the introduction of PoCT in the general practice setting.

Very few of the studies published in the literature since Hobbs et al. are RCTs and none are sufficiently similar to be combined in a meta-analysis. The trials differed significantly from each other with respect to study design, types and combinations of intervention, timing and study populations investigated. The subject numbers examined were generally small and the duration of the PoCT intervention was usually short.

In terms of clinical effectiveness, our review showed that no trial found a significant difference between PoCT and pathology laboratory testing. It is important to note that four of the five trials evaluating between-group (intervention and control) differences in therapeutic control did not investigate PoCT solely but included another intervention making it difficult to determine whether treatment differences were masked because of multiple interventions. Our review showed that three trials found within-group improvements in test results after the introduction of PoCT. However, there are difficulties in generalizing these results to the broader population because the results of these studies could be explained by the Hawthorne effect. Interestingly, the two trials investigating the impact PoCT had on clinical decision making showed significant improvement in clinical decisions in the PoCT group compared to the control group.

Studies relating to the analytical quality of PoCT by comparing agreement of PoCT results to laboratory results are limited, with only one trial investigating the agreement between PoCT and pathology laboratory for INR testing. It is not surprising perhaps that there was only one trial assessing the analytical quality of PoCT compared to pathology laboratory testing because this outcome can be more easily assessed in an observational study. However, results from the one study that focused on the bias between PoCT and laboratory results concluded that the results were clinically acceptable but did not report the 95% limits of agreement. Drawing firm conclusions from studies using more valid statistical methods such as Bland–Altman analyses are also difficult because of the different measurement technologies used for both PoCT and in the laboratory.

Conclusions about the costs of PoCT are also difficult to draw because of limited studies with variable analyses and findings. Only two trials looked at cost-effectiveness, both from the perspective of cost to society (health care provider). As noted above, the results were not consistent other than the results being sensitive to particular costs and altering these changed the outcome. The trials investigating cost also...
provided little detail on how these data were collected and allocated to the intervention and control groups. There is also a paucity of evidence relating to patient and health professional satisfaction. There was only one trial that completed comparative analyses between patients in the intervention (PoCT) and control group (pathology laboratory testing) that showed no statistical difference. This deficiency combined with small patient and health professional numbers requires future research.

Limitations
This review only focused on seven point-of-care tests for the management of patients with established chronic disease in general practice. This limited test selection may result in some bias in our conclusions. However, the review provides a relevant and meaningful summary to help inform decisions around the implementation of these point-of-care tests in the general practice setting.

Also, because there is no standard definition of PoCT, it is possible that some published papers could have been missed. This limitation was noted in the Hobbs et al. systematic review and remains the case today.

Future research
Further research is required to inform policy decisions of whether PoCT should be implemented in the general practice setting. As it is not intended for PoCT to replace laboratory testing in the current setting but rather to provide a practical and timely alternative of equivalent quality, future studies for the three conditions evaluated in this review should focus on conducting non-inferiority trials to determine the safety and clinical effectiveness of PoCT. This type of analysis would allow the identification of whether PoCT is as effective as the standard procedure of laboratory testing so that the two methods can be used interchangeably in the general practice setting.

Supplementary material
Supplementary Table 1 is available at *Family Practice* online (http://fampra.oupjournlas.org/).

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