Effectiveness of non-cardiac preoperative testing in non-cardiac elective surgery: a systematic review

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Editor’s key points

- This review intends to systematically review the evidence for modes of preoperative testing in elective non-cardiac surgery patients.
- The authors have reviewed evidence from the years between 2001 and 2011.
- Importantly, routine preoperative testing in healthy adults was not found to add any value to their management.

Summary. Elective surgery is usually preceded by preoperative diagnostics to minimize risk. The results are assumed to elicit preventive measures or even cancellation of surgery. Moreover, physicians perform preoperative tests as a baseline to detect subsequent changes. This systematic review aims to explore whether preoperative testing leads to changes in management or reduces perioperative mortality or morbidity in unselected patients undergoing elective, non-cardiac surgery. We systematically searched all relevant databases from January 2001 to February 2011 for studies investigating the relationship between preoperative diagnostics and perioperative outcome. Our methodology was based on the manual of the Ludwig Boltzmann Institute for Health Technology Assessment, the Scottish Intercollegiate Guidelines Network (SIGN) handbook, and the PRISMA statement for reporting systematic reviews. One hundred and one of the 25 281 publications retrieved met our inclusion criteria. Three test grid studies used a randomized controlled design and 98 studies used an observational design. The test grid studies show that in cataract surgery and ambulatory surgery, there are no significant differences between patients with indicated preoperative testing and no testing regarding perioperative outcome. The observational studies do not provide valid evidence that preoperative testing is beneficial in healthy adults undergoing non-cardiac surgery. There is no evidence derived from high-quality studies that supports routine preoperative testing in healthy adults undergoing non-cardiac surgery. Testing according to pathological findings in a patient’s medical history or physical examination seems justified, although the evidence is scarce. High-quality studies, especially large randomized controlled trials, are needed to explore the effectiveness of indicated preoperative testing.

Keywords: adult; diagnostic tests, routine; preoperative procedures; review, systematic; surgical procedures, operative

Accepted for publication: 27 December 2012

It is estimated that 234.2 million major surgical procedures are undertaken every year worldwide.1 Preoperative diagnostics usually precede elective surgery to minimize perioperative risk. The results of preoperative testing are assumed to predict complications which may lead to preventive measures or even cancellation if potential harm exceeds the benefit of surgery. Moreover, physicians consider some preoperative tests such as electrocardiogram or red blood count to be a valuable baseline assessment for the detection of subsequent changes. We know little about the effectiveness of these tests. Thus, surgical patients often undergo extensive preoperative diagnostics without a background of sound evidence that diagnostic benefit outweighs costs and potential harm. Therefore, various studies2–4 and also health technology assessments and guidelines5–7 widely criticize the usual practice of extensive, non-selective

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testing. Some authors report that, based on patient history and physical examination, 60–70% of laboratory tests ordered before general surgery are not required. In a recently published study, we could demonstrate that restricting preoperative diagnostics to the recommendations of the current guideline of the Austrian Society of Anaesthesiology (OEGARI) would lead to annual savings of 10–35 m € in Austria. These findings confirm the results of an earlier published study. Adherence to guidelines on preoperative testing by physicians or even hospitals is often poor.

The Austrian guideline mentioned above has incorporated international guidelines—like the guideline of the National Institute for Health and Clinical Excellence (NICE) of 2003, the guideline of the American Heart Association (AHA) of 2007, and the Practice Advisory for Preanesthesia Evaluation of the American Society of Anaesthesiologists (ASA) of 2012. These guidelines all agree that the practice of preoperative routine diagnostics is neither justified nor evidence-based. The NICE guideline is based on a HTA report of 1997 and a systematic literature update from 1966 to 2002. The HTA report identified 70 studies regarding specified preoperative diagnostics and concludes that very limited data exist on the frequency of perioperative complications and their relation to preoperative tests. The NICE review identified 26 additional relevant studies from 1997 to 2002 that did not change the conclusions of the HTA report. Furthermore, the NICE review identified 21 studies dealing with preoperative pregnancy testing, lung-function tests, and blood gas analysis which had not been included in the HTA report. Here again, the NICE report did not find evidence to justify unselective preoperative screening of healthy individuals if there are no specific reasons for testing derived from patient history or physical examination. Similar conclusions were drawn from the systematic literature review performed by the AHA in 2007 to evaluate cardiac preoperative diagnostics.

As the literature search of the NICE guideline included only studies published before March 2002, there is a strong need to update the available evidence regarding non-cardiac preoperative testing to renew and strengthen current recommendations. Neither the recently published Practice advisory for preanaesthesia evaluation of the ASA nor the ESA’s guideline for preoperative evaluation of the adult patient undergoing non-cardiac surgery from 2011 fulfil this need. We therefore conducted a systematic review of the literature on preoperative testing in non-cardiac surgery from 2001 to 2011, based on the findings of the NICE review of 2002.

Our research questions focus on the effectiveness of non-cardiac preoperative testing in elective non-cardiac surgery:

- Does preoperative laboratory testing [full blood count, haemostasis, blood gases, renal function, liver function, electrolytes, C-reactive protein (CRP), pregnancy screening, urine analysis, or a set of any of these procedures] lead to changes in clinical management, or does it reduce peri- and postoperative complications such as mortality or morbidity (including complications and adverse events) in unselected patients undergoing elective, non-cardiac surgery?

We used two approaches to search for evidence regarding the effectiveness of preoperative diagnostics. One approach looked at comparisons of a set of preoperative tests (test grid) being routinely performed vs being not performed. The other approach focused on specific preoperative tests analysed separately.

**Methods**

To provide an update of the NICE review mentioned above, we systematically searched the literature from 2001 to 2011 for studies on the effectiveness of preoperative testing in elective non-cardiac surgery. As the NICE guideline covers the literature from 1966 to February 2002, we selected this time frame to provide sufficient overlap with the NICE search. The methodology of this systematic review is based on the manual of the Ludwig Boltzmann Institute for Health Technology Assessment, Vienna, the Scottish Intercollegiate Guidelines Network (SIGN) handbook, and the PRISMA statement for reporting systematic reviews.

**Literature search**

We developed a comprehensive search strategy to identify all publications relating to generic preoperative testing. The systematic literature search was conducted on February 3, 2011, searching: Ovid Medline (Medical Subject Headings and free text search), Embase, DARE-NHSEED-HTA (INAHTA), and The Cochrane Library. We limited the search to the years January 2001–February 2011. Search terms used in Ovid Medline and Embase are listed in Table 1. Population (A), study design and outcomes (B), and search strings for specific tests (C) were combined with ‘AND’ (A and B and C). The search terms within the three main categories (A, B, and C) were combined with ‘OR’. In addition, we searched health technology assessments by accessing the following sites: NHS Institute for Health and Clinical Excellence (nice.org.uk/Guidance/), Canadian Agency for Drugs and Technologies in Health (cadth.ca/index.php/en/home), and National Coordinating Centre for Health Technology Assessment (ncchta.org/research/index.shtml). Finally, we also conducted a hand search reviewing the references of the included studies. The full search strategy is available in Supplementary Appendix SI.

**Inclusion criteria**

We designed a PICOS framework (Population, Intervention, Control, Outcome, Study design) to identify controlled
studies, and used its elements as primary selection criteria. Articles were regarded as potentially eligible if they met all of the criteria depicted in Table 2.

**Exclusion criteria**

We excluded the following publication types: case series, pilot studies, studies only reporting data on prevalence or incidence, abstracts, comments, editorials, letters, news, qualitative studies, narrative reviews, and economic studies not based on own original data.

The following procedures were excluded: acute interventions (non-elective surgery), cardiac procedures (e.g. percutaneous coronary interventions, coronary artery bypass grafting, valve surgery, surgery of the ascending thoracic aorta), percutaneous endovascular interventions, angiography, stent placement, and transplant surgery (e.g. liver, lung, kidney, heart). Prognostic or outcome studies for surgery in malignant tumours reporting on, for example, long-term survival after lung resection due to lung carcinoma, were also excluded.

**Selection and data extraction**

Two reviewers independently screened each title and abstract of a potentially eligible report identified in electronic database and hand searches using Reference Manager® Version 12.0, with the help of a standardized internal manual. Each article was categorized into one of the three groups: ‘yes’ (based on title and/or abstract, seems to meet inclusion criteria), ‘no’ (does not meet the inclusion criteria), and ‘background’ (useful background material). Six extraction tables and a data extraction form, including a set of parameters for extracting relevant information on preoperative testing, were created. One reviewer extracted the data and a second reviewer independently checked the completeness by reviewing the extraction tables and full-text articles. We required general agreement for inclusion or exclusion of each identified publication. Disagreement between the two researchers was resolved by discussion, and if necessary by arbitration of the senior researcher (A.S.).
Preoperative tests

BJA

Assessing study quality and level of evidence

The SIGN handbook was used to grade the level of evidence of each included study (Table 5).

Results

Included articles

The electronic database searches identified 25,281 articles. After removal of 127 duplicates, we considered 25,154 articles for further analysis. After reviewing titles and abstracts, 24,707 studies were excluded by our exclusion criteria, and 447 articles were ordered for full-text analysis. Of these, we included 97 studies, three randomized controlled trials (RCTs), and 94 observational studies. Four additional observational studies were identified by hand search, making a total of 101 studies. Table 6 shows the results of the literature search. Figure 1 illustrates the PRISMA flowchart of this systematic review.

The three RCTs evaluated the use of test grid vs no testing or selected testing in non-cardiac surgery (Supplementary Appendix SIV). We further included 39 studies regarding preoperative pulmonary evaluation: spirometry, chest X-ray, and blood gases (Supplementary Appendix SV). We also identified 39 studies evaluating preoperative haemoglobin and haematocrit testing (Supplementary Appendix SIV). We further included 39 studies evaluating white blood count testing and four studies on CRP were included (Supplementary Appendix SVIII). None of the eligible studies covered preoperative haemostasis testing (Supplementary Appendix SVIII). A total of 25 studies analysed the effectiveness of preoperative renal function tests, urine analysis, and electrolyte tests (Supplementary Appendix SIX). Seven studies evaluating preoperative liver function testing were included (Supplementary Appendix SX) and one study on pregnancy testing were also included (Supplementary Appendix SXI).

Clinical outcomes of the included studies

Test grid studies

Two single-centre RCTs analysed the use of test grids in patients undergoing cataract surgery and/or the ACC/AHA 2007 Guidelines on Perioperative Cardiovascular Evaluation and Care for Non-cardiac Surgery (Table 4).

Detailed information about the data extraction form is provided in Supplementary Appendix SII. The extraction tables with the included studies are available in Supplementary Appendices SIII–SXI. The data extraction of the included studies is provided in the tables as given in these Supplementary appendices.

If available, the patients’ physical status according to the classification of the ASA was recorded (Table 3). The severity of surgical procedures was categorized for each study according to the ESC Guidelines for preoperative cardiac risk assessment and perioperative cardiac management in non-cardiac surgery and/or the ACC/AHA 2007 Guidelines on Perioperative Cardiovascular Evaluation and Care for Non-cardiac Surgery. Detailed information about the data extraction form is provided in Supplementary Appendix SII. The extraction tables with the included studies are available in Supplementary Appendices SIII–SXI. The data extraction of the included studies is provided in the tables as given in these Supplementary appendices.
A single-centre RCT was performed on patients undergoing elective minor invasive procedures. A variety of perioperative outcomes (morbidity, complications, and adverse events) was reported in the included studies (Supplementary Appendix SIV). Preoperative testing before cataract surgery did not affect outcome parameters in two studies. Preoperative medical testing neither reduced the rate of intra- or postoperative ophthalmic complications (relative risk (RR) 0.73, 95% confidence interval (CI) 0.29–1.78 and RR 0.83, 95% CI 0.26–2.72, respectively) nor the rate of intraoperative systemic adverse events (RR 1.0, 95% CI 0.25–3.98) in the trial performed by Cavallini and colleagues when compared with no testing. Postoperative systemic events did not occur in either group. In the second study analysed, the cumulative rate of medical events was 9.6% in the routine testing group compared with 9.7% (P = 0.923) in the selective testing group.

Diagnostic testing before ambulatory surgery neither reduced the incidence of intra- and postoperative adverse events (RR 1.0, 95% CI 0.4–3.0 and RR 0.8, 95% CI 0.4–1.5, respectively) nor the rate of hospital revisits 8–30 days after surgery compared with no testing. Hospital revisits within 7 days were significantly more frequent in the testing group compared with no testing (RR 0.4, 95% CI 0.2–0.9). No study analysed whether the use of routine preoperative test grids reduced the incidence of changes in clinical management compared with no testing or selective testing. No deaths were reported in the studies and therefore no further analysis regarding mortality was done.

### Accuracy and predictive value of test grids

None of the included studies provided information on the accuracy and predictive value of the test grid used regarding mortality, complications, or changes in management.

| Table 6 Literature search results: number of studies identified, excluded, and included by single preoperative test. RCT, randomized controlled study; PT, prothrombin time; PT, activated partial thromboplastin time; PC, platelet count; INR, international normalized ratio; BUN, blood urea nitrogen; GFR, glomerular filtration rate; CrCl, creatinine clearance; ALT, alanine aminotransferase; GPT, glutamic pyruvic transaminase; AST, aspartate aminotransferase; GGT, glutamic oxaloacetic transaminase; AP, alkaline phosphatase; GGT, gamma-glutamyl transferase. *Including studies obtained by hand search. †The total number of studies does not equal the sum of the test-specific studies because most studies investigated more than one test. |

<table>
<thead>
<tr>
<th>Preoperative test</th>
<th>Full-text articles assessed for eligibility*</th>
<th>Excluded studies</th>
<th>Included studies by hand search</th>
<th>Cohort study prospective</th>
<th>Cohort study retrospective</th>
<th>Case-control</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test grid</td>
<td>447*</td>
<td>352†</td>
<td>4†</td>
<td>27</td>
<td>59</td>
<td>9</td>
<td>6</td>
<td>101</td>
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<tr>
<td>Spirometry</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
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<tr>
<td>Chest X-ray</td>
<td>38</td>
<td>36</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Blood gases</td>
<td>22</td>
<td>15</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Haemoglobin, haematocrit</td>
<td>126</td>
<td>87</td>
<td>1</td>
<td>10</td>
<td>25</td>
<td>4</td>
<td>0</td>
<td>39†</td>
</tr>
<tr>
<td>White blood cell count</td>
<td>118</td>
<td>110</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>C-reactive protein</td>
<td>28</td>
<td>24</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Haemostasis tests (PT, aPTT PC, INR)</td>
<td>60</td>
<td>51</td>
<td>4</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Renal function tests (creatinine, BUN, GFR, CrCl)</td>
<td>67</td>
<td>44</td>
<td>4</td>
<td>6</td>
<td>17</td>
<td>0</td>
<td>0</td>
<td>23†</td>
</tr>
<tr>
<td>Urine analysis</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Electrolytes (sodium and potassium)</td>
<td>28</td>
<td>23</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Liver function tests (ALT/GPT, AST/GOT, AP, GGT, total bilirubin)</td>
<td>39</td>
<td>33</td>
<td>0</td>
<td>1</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Pregnancy tests</td>
<td>9</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

* Including studies obtained by hand search. † The total number of studies does not equal the sum of the test-specific studies because most studies investigated more than one test.
Pulmonary evaluation; spirometry, chest X-ray, blood gases

Twelve overall heterogeneous cohort studies demonstrated a variety of correlations between significantly restricted lung function and perioperative morbidity and mortality (Supplementary Appendix SV, table b). However, there was no valid evidence supporting routine (unselective) spirometry in asymptomatic patients. There was no valid evidence supporting routine (unselective) chest X-ray. Neither of the two studies included investigated the association between the test and changes in clinical management or 30 day mortality. Postoperative pulmonary complications occurred in 2.7–58.3% of the patients. Neither study showed a significant association between abnormal tests and postoperative pulmonary complications. However, this result is of only limited validity as it was not confirmed by multivariate analysis. In summary, we did not find evidence to support routine (unselective) preoperative blood gas analysis in patients without history of pulmonary disease.

Accuracy of preoperative pulmonary evaluation

The accuracy of spirometry regarding outcome morbidity, complications, and adverse events ranged from 40.9% to 94.3% with positive predictive values from 7.1% to 81.8% depending on setting, selection of patients, and cutoff values used.

Haemoglobin and haematocrit

We included 35 cohort studies (nine prospective, 26 retrospective) and four case–control studies which assessed the correlation between preoperative haemoglobin or haematocrit testing and peri- or postoperative outcomes (Supplementary Appendix SVI). None of these studies offered a controlled comparison between
preoperative testing and no testing. Thus, the efficacy of the diagnostic intervention cannot be estimated directly.

The studies demonstrated a strong correlation between low haemoglobin levels and the risk for peri- and postoperative blood transfusions, but all studies included healthy subjects and patients with pre-existing anaemia or haematological disease, explaining the correlation.

Overall, these results do not permit the conclusion that lower haemoglobin and haematocrit levels are generally correlated to peri- or postoperative complications in healthy subjects without clinical signs or history of anaemia or haematological disease.

In summary, we did not find valid evidence suggesting that routine preoperative haemoglobin or haematocrit testing will lead to a change in clinical management or outcome in patients without pre-existing conditions or signs of anaemia in clinical examination and medical history.

**Accuracy of haemoglobin and haematocrit**

One study provided data on the accuracy and positive predictive value for 24 h mortality. The accuracy at a lower cut-off of haematocrit <38 was 75.9% with a positive predictive value of only 0.15%. With an upper cut-off of haematocrit >45, the accuracy was 77.9% with an extremely low positive predictive value of 0.05%. No study provided any information about the accuracy of haemoglobin testing.

**White blood cell count and CRP testing**

Eight studies evaluating the effectiveness of preoperative white blood cell (WBC) count testing and four CRP testing studies were included (Supplementary Appendix SVII). All studies used a cohort study design and were very heterogeneous. Seven of them were retrospective. Three studies using a multivariate analysis found correlations between an abnormal test and perioperative morbidity and mortality, but included patients with known inflammatory diseases explaining the correlation. There was no valid evidence supporting routine (unselective) preoperative WBC or CRP testing in asymptomatic patients.

**Accuracy of WBC testing**

The accuracy and positive predictive value for 24 h mortality were provided in one study. With an upper cut-off of WBC >11 000 mm$^3$, the accuracy was 90.2% with a positive predictive value of only 0.15%. No study provided any information on the accuracy of CRP testing.

**Haemostasis testing**

We included nine very heterogeneous cohort studies analysing the effectiveness of preoperative haemostasis testing (Supplementary Appendix SVIII). Six studies used a retrospective study design, and three were prospective trials. No study investigated the association of haemostasis testing and changes in clinical management. Six studies using a multivariate analysis investigated the incidence of adverse events and morbidity whereas three studies reported on mortality.

Two studies found a correlation between an abnormal platelet count and an abnormal international normalized ratio test and the outcomes ‘adverse events’ or ‘morbidity’ in patients undergoing elective abdominal surgery. One study found a correlation between an abnormal prothrombin time and an abnormal platelet count and mortality in patients undergoing miscellaneous surgeries.

In summary, we did not find valid evidence suggesting that routine preoperative haemostasis testing will lead to a change in clinical management or outcome in asymptomatic patients.

**Accuracy of platelet count testing**

One study reported on the accuracy and positive predictive value for 24 h mortality. The accuracy using an abnormal platelet count definition of platelet count <150×10$^3$ mm$^3$ was 94.1% with a positive predictive value of 0.8%. With an upper cut-off of platelet count >400×10$^3$ mm$^3$, the accuracy was 94.7% with a positive predictive value of 0.1%. The accuracy of other haemostasis tests evaluated in this systematic review was not provided by any of the included studies.

**Renal function tests, electrolytes, and urine analysis**

We included 25 cohort studies which reported the correlation between renal function tests, electrolyte tests, or urine tests and perioperative changes in clinical management, mortality, and morbidity. Twenty-three studies evaluated renal testing, five studies electrolyte testing, and one study urine testing. Seven studies were prospective cohort studies; the remaining 18 studies had a retrospective design. Two studies included low-risk procedures whereas the rest of the trials examined intermediate- or high-risk surgery. Thirty day mortality was recorded in 11 studies. Odds ratios (ORs) for mortality were between 1.2 and 8.1 for abnormal vs normal test results. A significant correlation between test results and mortality was found in eight studies. In three studies, the impact of testing on mortality was not significant. The included studies showed great heterogeneity regarding their reporting of complications. Only 11 of the 23 studies revealed a positive correlation between pathological renal function tests and the occurrence of complications (ORs ranging from 1.42 to 9.62). All these studies included patients with known pre-existing renal disease explaining the correlations. In six studies, no significance was found whereas six studies did not provide data on complications. Five studies reported that the correlation between complication rates and an abnormal creatinine clearance test or estimated glomerular filtration test was stronger than the correlation between complications and an abnormal serum creatinine test.
Accuracy of preoperative renal function testing, electrolytes, and urine analysis

Studies analysing serum creatinine test for the outcome morbidity, complications, and adverse events had an accuracy from 62.0% to 98.3% with positive predictive values ranging from 0.1% to 59.5% (different cut-offs used, 120–176 μmol litre⁻¹).63 64 66 109 The accuracy of serum creatinine test for the outcome mortality ranged from 79.2% to 89.4% with positive predictive values ranging from 0.15% to 53.3%.76 111 112 The accuracy of electrolyte testing for the outcome 24 h mortality ranged from 90.6% to 98.3% with positive predictive values ranging from 0.2% to 0.1% (different cut-offs used, Na⁺ <135 mmol litre⁻¹ to Na⁺ >145 mmol litre⁻¹).76 The accuracy of urine analysis (positive dip-stick) for surgical site infection was 80.4% with a positive predictive value of 38.5%.117 The accuracy of other renal function tests, electrolyte tests, and urine analysis evaluated in this systematic review was not provided by the included studies.

Liver function testing

We included seven studies analysing the correlation between liver test results and perioperative mortality and morbidity. None of the studies investigated the association between liver function tests and changes in clinical management (Supplementary Appendix SX).

All studies used a cohort study design and were very heterogeneous. Five studies were retrospective62 69–71 108 and two study was prospective.76 121 Three studies69 71 108 using a multivariate analysis reported on adverse events and morbidity, whereas two studies provided data on mortality.71 76 Only one study found a correlation between an abnormal total bilirubin, aspartate aminotransferase, or alkaline phosphatase and mortality.76 However, there was no valid evidence supporting routine (unselective) liver tests in asymptomatic patients.

Accuracy of liver testing

One study provided data on the accuracy and positive predictive value of liver testing for 24 h mortality.76 The accuracy of alkaline phosphatase (>125 units litre⁻¹) testing was 91.1% with a positive predictive value of 0.2%. The accuracy of aspartate aminotransferase (>40 units litre⁻¹) testing was 91.7% with a positive predictive value of 0.17%. The accuracy of total bilirubin (>1.0 mg dl⁻¹) testing was 93.6% with a positive predictive value of 0.23%. The accuracy of other liver tests evaluated in this systematic review was not provided by the included studies.

Pregnancy testing

One study evaluated preoperative pregnancy testing (hCG test in urine) in patients undergoing elective orthopaedic surgery (Supplementary Appendix SXI). Positive pregnancy tests were found in eight (0.31%) of 2588 patients. In seven of these patients, a serum-hCG test was performed to confirm the result. Four tests were positive and three negative. One woman refused the test. The surgery was delayed in the women with a positive serum-hCG test and in the woman refusing the test.122

Accuracy of pregnancy testing

The accuracy of preoperative pregnancy testing regarding the detection of pregnancy was calculated to be 99.8%, with a positive predictive value of 50%.122

Quality of studies and level of evidence

Randomized controlled studies

In all three RCTs analysing the use of test grids, both the intervention group and the control group were well balanced with respect to age, sex, and risk of perioperative complications and also co-morbidities. A systematic randomization method was used in all the studies assessing the study group allocation. The study personnel adequately concealed the allocation in two of the three studies.24 25 All studies recruited the patients consecutively and used a single-blinded approach.24–26 Intraoperative outcomes were assessed from clinical records at the time of discharge. Postoperative complications were assessed by telephone interview 1 month after surgery. Physicians performing the preoperative tests knew for which patients to conduct preoperative testing.76 Neither of the studies reported losses to follow-up. All included RCTs have a high risk of bias and therefore are categorized as a level of evidence of 1—using the Scottish Intercollegiate Guidelines Network SIGN (www.sign.ac.uk) Levels of Evidence.20

Observational studies

We did not find controlled intervention studies for single tests, which directly referred to our PICOS framework (does preoperative testing reduce peri- or postoperative mortality...
or morbidity compared with no testing?). The best available evidence is therefore derived from cohort studies and case–control studies with rather small populations. The majority of the studies are retrospective, and in many cases, a clear reporting on a prospective or retrospective design is lacking. This implies considerable risk for selection bias, incomplete documentation of data, and confounding. Retrospective cohort studies should be used in developing or strengthening hypotheses, which requires very large populations. Thus, overall quality of included studies has to be classified as rather low.

Only four studies21 53 76 82 were graded 2+ according to the level of evidence defined by SIGN; all other studies were graded 2−. Studies with a grade of <2− were not included in our review (see the Inclusion/exclusion criteria sections).

Discussion
Routine preoperative testing in healthy adults undergoing elective non-cardiac surgeries is of questionable benefit, and therefore has already been comprehensively rejected by credible reviews/guidelines and authorities in many countries. In contrast to these recommendations, unselective preoperative testing still is a common standard component preceding elective surgery. The question that still is controversially discussed among some experts is whether we can reduce or eliminate preoperative laboratory testing without any disadvantages for the patient. To explore this question, we cannot use superiority studies, which aim at providing evidence that, for example, a new therapy or diagnostic procedure is more efficient than the state of the art. A more appropriate study design in this case would be equivalence or non-inferiority studies, which aim at the demonstration that the intervention under investigation is not worse than the comparator. First, these study designs require another statistical approach, secondly and most of all these trials have to enrol very large numbers of patients. Such studies have never been performed in the evaluation of preoperative testing. In addition to this, it needs to be mentioned that data on minor surgical procedures are very scarce. The mere presentation of this correlation predicts perioperative outcome. We undoubt-

The three test grid RCTs included in this systematic review, two involving cataract surgeries and one study covering various types of ambulatory low-risk procedures, do not provide any evidence that preoperative testing might provoke changes in clinical management or reduce morbidity or mortality. It may be considered a limitation that Chung and colleagues25 only included patients undergoing ambulatory surgery, prohibiting an extrapolation of these results to other settings. On the other hand, the surgical procedures examined included operations performed on patients with significant co-morbidity (>10% classified ASA III), neurosurgery, and spine surgery,25 which are usually performed in an in-hospital setting throughout Europe. This aspect increases the value of the findings of this study for many institutions. Furthermore, the absence of evidence for the benefit of routine preoperative testing in the ambulatory setting does not imply that this benefit could possibly be shown in the in-hospital setting or in operations with a higher risk of perioperative complications. In these settings, we simply do not have any randomized controlled studies supporting or not supporting routine testing.

Although the risk of bias in the three studies included in this review was high, a recently published Cochrane review 2009124 on routine preoperative medical testing for cataract surgery came to the same result. It stated that preoperative medical testing did not reduce the risk of intraoperative (OR 1.02, 95% CI 0.85–1.22) or postoperative (OR 0.96, 95% CI 0.74–1.24) medical adverse events when compared with selective or no testing. The Cochrane review included the two studies reviewed in this systematic review and a third large-scale RCT published by Schein and colleagues3 in 2000 which has been included in the NICE review but not in this systematic review due to the time-frame of our search.

Besides the three RCTs described above, current evidence on preoperative testing is mainly based on low-quality observational studies, mostly retrospective cohort studies or case series. Overall, the very heterogeneous studies are using different outcome measures and varying abnormal test definitions impeding evaluation. Most of the included studies recruited mainly elderly patients with a variety of co-morbidities who were undergoing intermediate- or high-risk surgeries. Thus, the correlations between preoperative test results and outcome rather reflect the correlation between pre-existing co-morbidity and outcome than a consequence of pathological preoperative test results. In addition to this, it needs to be mentioned that data on minor surgical procedures are very scarce. The mere presentation of this correlation does not permit the conclusion that preoperative testing per se predicts perioperative outcome. We undoubt-

edly have to perform the necessary tests to take care of existing disease before operation, but this does not imply a necessity to perform these tests in otherwise healthy subjects where, based on history, symptoms, and physical findings, we do not suspect the presence of underlying disease.

There is no evidence at all to support routine preoperative testing in a younger population undergoing low-risk
surgical procedures—the majority of the patients presenting for non-cardiac surgery in clinical practice.

We found a correlation between pathological preoperative tests and outcome in many of the studies in our systematic review. This suggests that preoperative testing in adults undergoing elective, non-cardiac surgery should be performed in selected patients, that is, patients with pre-existing diseases or risk factors, or if the patients' history and physical examination reveal indications for such conditions. Thus, the results of our review strongly confirm the NICE guideline which only recommends preoperative testing if the patient's history and physical examination reveal an indication. Spirometry should only be performed in patients with pre-existing pulmonary diseases or risk factors, or if symptoms such as dyspnoea (on exertion), coughing, or signs of airway obstruction. Haemoglobin and haematocrit need to be examined if there are anaemic or clinical signs of anaemia or haematological disease. The correlation between haemoglobin, haematocrit, and the need for perioperative transfusions were seen in some of the studies is due to the inclusion of patients with these disorders. None of the studies showed that haemoglobin testing of healthy, asymptomatic patients does any good.

Similarly, WBC and CRP should only be performed in selected patients, for example, with risk factors, clinical signs of systemic inflammation, or if the patients' history and physical examination reveal indications for such conditions. Preoperative WBC and CRP testing seems reasonable in orthopaedic (joint replacement) surgeries to exclude a systemic inflammation predisposing for infection of the endoprosthesis.

Haemostasis testing and liver testing as well should only be performed in patients with risk factors, history, or physical examination raising suspicion for such conditions.

The strength of our systematic review is its rigorous and extensive search of the literature, and a scrutinious evaluation and selection of relevant studies by at least two independent researchers. It may be considered a limitation that we restricted our search to the years 2001–2011, and that we did not perform a synopsis of all studies retrieved by the NICE search and our search, thus giving an overview of all relevant studies from 1966 to 2011. The high reputation of the NICE allowed us to rely on the HTA and systematic review performed by NICE up to February 2002, and we provide an overlap of more than 1 yr with the NICE review to assure that no relevant studies are missed. Taken together, the NICE review, its preceding HTA, and our systematic review cover the literature from 1966 to February 2011, and it is unlikely that relevant trials might have been missed by these searches. Also, the findings of our systematic review do not differ relevantly from the NICE results and it is unlikely that relevant trials might have been missed by these searches. The observational studies included show that preoperative testing in adults undergoing non-cardiac surgery did not induce changes in clinical management, and did not affect mortality, morbidity, or the frequency of adverse events in otherwise healthy subjects. Performing preoperative tests according to a patient's medical history and physical examination seems justified, although high-level evidence from clinical trials does not exist. It seems reasonable to believe that preoperative testing may reduce adverse outcomes in patients undergoing elective non-cardiac surgical procedures only if the test would have been performed anyway in symptomatic subjects. This recommendation is well in accordance with the NICE guideline from 2003.

More research, especially large-scale multicentre RCTs, would be necessary to explore the effectiveness of indicated preoperative testing compared with no testing in elective surgery to support clinicians and policy makers in making informed decisions.

**Supplementary material**

Supplementary material is available at *British Journal of Anaesthesia* online.

**Declaration of interest**

None declared.

**Funding**

This work was supported by the Austrian Federal Ministry of Health and the Austrian Society of Anaesthesiology, Resuscitation and Intensive Care Medicine.

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Handling editor: R. P. Mahajan