

Intraoperative point-of-care testing

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Abstract

Point-of-care devices offer an increasing number of analytical tests more quickly than laboratory analysis, but clinicians must be aware of the limitations of these devices, especially for critical threshold-level decisions. Glucometers are susceptible to a wide range of errors, and only a few haemoglobin-measuring devices have accuracy approaching that of laboratory analysis. Activated coagulation time remains a useful but error-prone test for heparin effects. Thromboelastography and thromboelastometry offer insight into coagulation defects superior to conventional assays. Multi-function testers provide cardiac enzyme and lactate analysis that is becoming vital for intraoperative decision-making.

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Introduction

Recent advances in technology have made obtainable a range of point-of-care devices that can perform clinical analyses to anaesthesiologists which until recently, were only available from laboratories. Increasingly rapid access to some of these tests may well change anaesthetic practice, but the benefits, pitfalls and limitations of point-of-care devices must be appreciated.

Glucometers

Hypoglycaemia kills neurones, and hyperglycaemia aggravates inflammatory damage and impairs wound healing and immunity. Both must be avoided intraoperatively. A laboratory assay of plasma glucose concentration is accurate, but is impractically slow in an emergency. Glucometers measure whole blood glucose concentration within minutes, but with potential for errors that may influence patient safety. While measuring whole blood glucose concentration, glucometers make allowance for expected erythrocyte mass and display plasma glucose concentration equivalents to allow comparability with a laboratory assay, but the presence of hypertriglyceridaemia or paraproteinaemia will confound this, and glucometers will reflect pseudohypoglycaemia.

Extremes of haematocrit may also affect readings. Glucometers that use the more specific glucose oxidase enzymatic technique are affected by blood oxygen tension (hyperoxia causes underestimation of whole blood glucose concentration and hypoxia leads to an overestimation), and those using the glucose 1-dehydrogenase technique falsely interpret non-glucose sugars, such as icodextrin, as glucose. Therapeutic paracetamol levels cause falsely high and low whole blood glucose concentration measures in glucose oxidase and glucose 1-dehydrogenase glucometers, respectively. Catecholamine infusions can also lead to major errors in point-of-care device glucose readings. Most worryingly, all glucometers, even if well calibrated in the euglycaemic range, are significantly more prone to error in hypoglycaemic patients. Most devices tend to read falsely high, which may mean that hypoglycaemia is missed. For this reason, while 3.5 mmol/l is the conventional "alert line" for treating hypoglycaemia with a laboratory assay, some authorities recommend a value of 3.9 mmol/l with glucometer readings. There are major variances in accuracy between devices, and users are advised to access independent published comparative analyses before purchasing glucometers for critical use. This is exceptionally important in paediatric and neonatal critical care. Very few of the available glucometers are precise enough for safe use in these populations, and

expert group recommendations should be sought before purchases are made. Lastly, there is a predictable decrease in glucose concentration in simultaneously sampled arterial (highest), capillary and venous (lowest) blood. The blood sampling site must be standardised if comparisons are to be valid.¹

Haemoglobinometers

A laboratory assay uses techniques such as cyanohaemoglobin measurement in lysed blood to most accurately quantify total haemoglobin concentration, but this requires complex equipment. Spun capillary tube haematocrit measurement and simple light-absorption devices have been used for years at the bedside, but these are no more than rough indications. Blood gas analysers which quantify haemoglobin concentration via spectrophotometry of intact blood are only slightly more precise. The HemoCue[®] Hb201 (HemoCue AB, Ängelholm, Sweden) uses cuvettes containing chemicals which lyse blood and generate measurable azidemethaemoglobin, a similar concept to formal laboratory assay tests. The HemoCue[®] system is now widely used, has shown reasonable and reliable concordance with laboratory assays in various studies. The HemoCue[®] HC is typically within 1 g/dl of the laboratory assay haemoglobin concentration when arterial blood is used. Unsurprisingly, there are worse limits of agreement when capillary blood is used because of the greater possibility of sampling error. The clinician should be aware of these limits of agreement when patient haemoglobin concentration is close to a transfusion trigger.²

Activated coagulation time

Monitoring of therapeutic heparin effect is critical during any form of extracorporeal circulation using heparin anticoagulation. The laboratory assay-activated partial thromboplastin time (aPTT) is slow and has a nonlinear response relationship. The activated coagulation time, essentially a development of whole blood clotting time, shows a positive linear correlation with the heparin level. Clot initiation is via negatively charged molecules included in the assay tube, selected according to the expected heparin level, e.g. glass beads for a moderate heparin level, celite for a high heparin level and kaolin for a high heparin level with aprotinin, with specific target value ranges for each activator. The various manufacturers' devices differ in methodological detail and also in their target ranges.³ Multiple preanalytical issues can affect activated coagulation time, hence samples must be carefully handled and clinicians should have a low threshold to repeat tests that yield unexpected results.

Thromboelastography and thromboelastometry

Bleeding diatheses commonly develop during emergency surgery, and can arise for many reasons, including hypothermia, platelet insufficiency or dysfunction, deficiency of one or more coagulation factors and premature thrombolysis. Conventional laboratory assays are frequently inadequate in directing therapy. They take too long and are non-specific. (The international normalised ratio is designed to measure the effects of warfarin, and aPTT to measure the effects of heparin).

Thromboelastography and thromboelastometry are related, but separately developed point-of-care device technologies that are superior to a laboratory assay for the purposes of directing haemostasis management. The TEG[®] (Haemoscope Corp, Braintree, USA) and ROTEM[®] (Pentapharm GmbH, München, Germany) use these respective techniques to analyse the dynamics of clot formation in real time by assessing the shear elasticity of clotting blood. Each device has specific advantages and some proprietary tests, but both will provide information within 5-20 minutes which will facilitate the identification of the presence of a platelet disorder, deficiency of clotting factors (especially fibrinogen), the presence of anticoagulants, and within 45 minutes, evidence of hyperfibrinolysis, thus allowing targeted therapy that is more efficient, has fewer side-effects and costs less than broad-spectrum "shotgun" blood product administration. Performing the analyses requires more attention than the typical point-of-care device, and so someone other than the patient's primary anaesthesiologist should probably run the test, but learning the technique of running the tests is within the capabilities of clinical staff in most theatre suites.^{4,5}

Blood gas analysers

The archetypal point-of-care device, blood gas analysers, have increased in convenience because of the development of cartridge technology that minimises the need for daily technologist maintenance, have improved in accuracy as multifrequency spectrophotometry has been added to conventional electrodes, and have acquired additional testing modalities, such as glucose and electrolyte measurement. Blood gas analysis *per se* is beyond the scope of this article, but the utility of the additional technologies is important. Blood gas analyser-based K⁺ analysis is usually accurate enough for clinical decision-making and ionised calcium (Ca²⁺), which is far more immediately useful than laboratory assay-based total Ca²⁺ measurement for the anaesthetist, and is readily available on many blood gas analysers.

Multifunction analysers

A range of handheld and desktop cartridge-based testing devices that offer multiple tests are now becoming available. Some machines offer full electrolyte panels that rival a laboratory assay in terms of accuracy and speed, although not usually cost, and some offer tests such as ACT, selected hormone levels and D-dimer levels. Several now incorporate assays for markers of myocardial necrosis [troponin (I or T) and creatine kinase-MB] which facilitate the earlier detection of perioperative myocardial infarction, the identification and subsequent correct early management of which is now the responsibility of the specialist anaesthesiologist. B-type natriuretic peptide levels have been increasingly shown to be of high importance in perioperative risk stratification of patients at risk of myocardial events,⁶ and several point-of-care devices now offer this.

Lactate analysis

Blood lactate concentration analysis is now incorporated on blood gas analysers and stand-alone devices. Lactate measurement is now seen to be essential in directing the resuscitation of shocked patients with type A lactic acidosis, as well as for the detection of hyperlactataemia and type B lactic acidoses from metabolic disorders, mitochondrial failure (such as with antiretroviral drug toxicity), and disorders of clearance. It also has a role in sports medicine. A test that once took a laboratory technician a whole day to perform is now available in minutes. Greater use means that there is now more debate about the significance of lactate levels in various pathologies, which is driving new physiological understanding.

The availability of multiple lactate analysers highlights a problem that can be generalised to all point-of-care devices. Simultaneous lactate levels measured on two devices are rarely identical, and correlation with a laboratory assay is sometimes poor.⁷ Furthermore, fingertip (capillary) lactate levels may differ substantially from arterial blood lactate levels. Absolute numbers are arguably less important than trends in response to therapy for some tests, including

lactate measurement. It may be acceptable for devices in such cases to produce different absolute numbers as long as their results all change in the same direction as any change in “true” blood levels. (Unfortunately, even this does not always happen with current lactate analysers). But when absolute levels are set in the literature as decision or trigger points for intervention, inaccuracies in point-of-care device values can have major implications on what treatment the patient receives. When using point-of-care devices for such “critical threshold level tests”, clinicians must pay attention to the quality of the devices they use, understand why different analytical techniques may produce different results, and develop awareness of issues like the limits of agreement between different analytical modalities. Clinicians rarely spend much time considering such issues. They are often regarded as the specialist realm of the chemical or clinical pathologist, but professional anaesthesiologists have a responsibility to research the workings of the point-of-care devices that they use in daily practice to guide their critical clinical decision-making.

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