# A survey of some pre-analytical errors identified from the Biochemistry Department of a Scottish hospital

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# A survey of some pre-analytical errors identified from the Biochemistry Department of a Scottish hospital

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## Abstract

**Background:** It is estimated that 70% of all health care decisions affecting diagnosis or treatment involve laboratory testing. The pre-analytical phase of the testing process shows the highest prevalence of errors accounting for 70% of all mistakes in laboratory diagnostics. It is recommended that laboratories collect statistics on pre-analytical error rates. This survey examined some mistakes in blood collection, i.e. specimen haemolysis, and EDTA contamination.

**Methods:** Survey was from June 2011 to May 2012. Haemolysis was detected by analysers' automated haemolysis index function. Plasma EDTA was measured by an automated system. Data were captured from our laboratory information management system.

**Results:** For a total workload of 763,577 blood specimens, the overall haemolysis rate was 3.2%. Much higher rates of both specimen haemolysis and EDTA contamination were observed when blood was not collected by trained phlebotomists.

**Conclusions:** Better training in blood collection, achieving the standard of professional phlebotomists, will improve validity of diagnostic information; reduce risks of dangerous misinterpretation of results, unwanted anaemia and needle-stick injury and decrease laboratory supplies costs. This type of audit could be replicated in other Scottish Health Boards with some benefit and thereby better target future training needs.

## Keywords

Phlebotomy, in vitro haemolysis, EDTA contamination, training

## Introduction

It is estimated that 70% of all health care decisions affecting diagnosis or treatment involve laboratory testing.[1] Any part of the laboratory cycle from ordering tests to reporting, interpreting and reacting to results can be subject to error.[2,3] There have been marked reductions in the rate of intra-laboratory errors due to improvements in information technology, introduction of internal and external quality assessment and better staff training.[4] Currently, the pre-analytical phase of the testing process shows the highest prevalence of errors accounting for 70% or more of all mistakes made in laboratory diagnostics, most commonly due to mistakes in blood collection, including specimen haemolysis, or contamination which are outwith the control of the laboratory and are poorly evaluated and monitored.[2–5] It is now recommended that clinical laboratories collect statistics on occurrence rates including pre-analytical phases of the whole testing cycle.[2,3]

In vitro haemolysis accounts for 40%–70% of all unsuitable blood specimens received in the biochemistry laboratory.[6] Its effects are variable, depend on test methodology and introduce an unnecessary degree of uncertainty on the reliability and validity of test results. It is caused by inappropriate collection and mishandling of the specimen.[6] In one recent close monitoring study conducted in a hospital emergency medicine department by Berg et al.[7], non-standard blood

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collection practice was common, and consequently almost one-quarter of blood specimens submitted to the laboratory were received haemolysed as a result.

Another form of pre-analytical error is contamination by potassium EDTA-containing anticoagulant present as an additive for full blood count (FBC) or glucose testing.[8] Some tests affected by the unwanted presence of potassium EDTA include potassium, calcium, magnesium, unsaturated iron-binding capacity (UIBC), bicarbonate, alkaline phosphatase, amylase, iron, ammonia or some immunoassays which are dependent on Europium or other lanthanide-based fluorescence.[8–11] If collected in a non-standard way and not in accordance with manufacturers' instructions, then in vitro EDTA contamination of biochemistry specimens may occur by (i) decanting of blood from EDTA-containing tubes, (ii) backflow by regurgitation of blood from an evacuated EDTA-containing tube[9,12] and (iii) carryover by transfer of liquid droplets of high-concentration EDTA solution via a syringe tip,[8,12–15] leading to subtle, undetectable, erroneous, yet entirely credible, laboratory results, e.g. hyperkalaemia and hypocalcaemia,[15–18] where misinterpretation of the findings may adversely affect patient care.[19] These forms of EDTA cross contamination are avoidable by complying with manufacturers' instructions and by observing the recommended order of drawing or filling when collecting blood into additive-containing tubes.[20,21]

The purpose of this survey was to extract data on the selected pre-analytical errors of in vitro haemolysis and EDTA contamination, and thereby identify and quantify the rates and sources of such errors which are occurring throughout our Health Board area.

## Methods

A routine phlebotomy service was available in each of the two district general hospitals (hospitals A and B) for outpatients (OPs) throughout the working day and for some selected inpatients (IPs) in the mornings. The phlebotomists did not collect blood from patients in the accident and emergency (A&E) departments. The Monovette® collection system (Sarstedt Ltd, Leicester, UK) was used throughout the survey employing liquid tri-potassium EDTA as anticoagulant in FBC testing and liquid sodium EDTA in combination with potassium fluoride as anticoagulant/preservative for glucose analysis. For routine biochemical testing, the usual specimen type was plasma where the lithium heparin additive is present in solid form as coated plastic beads.

The survey was from June 2011 to May 2012. Blood specimens were received from IPs, OPs and general practitioners (GPs) throughout the Health Board area. Routine biochemical analyses were performed on Roche Modular® analysers (Roche Diagnostics Ltd, Burgess Hill, UK). Haemolysis was defined as a haemolysis index >39 which is approximately numerically equivalent to a plasma haemoglobin concentration expressed in mg/dL.

Plasma specimens exhibiting potassium >5.5 mmol/L were automatically further analysed for EDTA concentration by an automated colorimetric technique.[22] All specimens for iron and total iron-binding capacity (TIBC) were also analysed for EDTA in order to avoid producing spuriously elevated UIBC values.[8] Further specimens found to be positive for EDTA, despite normokalaemia were identified at the stage of validation, reporting or authorisation by experienced laboratory staff by observing inconsistent findings for calcium, magnesium or potassium in sequential specimens from the same patient.

Using the laboratory computer, the sources of requests (IP, OP and GP) were determined. Weekends (Saturday + Sunday) were estimated separately from weekdays. The effect of staff involved in blood collection on the rates of haemolysis and EDTA contamination was determined by comparing all blood specimens received from OPs (phlebotomists) and the A&E department (other staff) for each of the two hospitals.

## Results

The total number of blood specimens received during the survey was 763,577 and those received in a haemolysed condition was 24,585, representing an annual overall haemolysis rate of 3.2%. The average weekday distribution of specimens by source was IP 27%, GP 61% and OP 12%. The weekday haemolysis rate was 2.9%. At weekends (Saturday + Sunday), >99% of specimens were from IPs, and the haemolysis rate was much higher at 7.3%. Overall, there were 528 specimens identified as positive for EDTA. The median (IQR) EDTA concentration was 0.58 (0.38–1.01) mmol/L. If the contamination had remained undetected, it would have led to spurious increments in apparent plasma potassium concentrations of approximately 1.0–3.0 mmol/L or more. There were 16,119 EDTA tests performed throughout the year of study. Of these, 9974 were associated with requests for iron and TIBC analysis, of which 21 were positive for EDTA. The remaining 6145 (i.e. 16,119 −9974) EDTA tests were associated with all other causes including plasma potassium >5.5 mmol/L. There was a disproportionate number (422 out of 528) of EDTA-contaminated specimens (80%) from hospital IP wards. The weekday distributions by source (IP, GP and OP), for haemolysed and EDTA-contaminated specimens, compared with the distributions expected from relative workload

**Table 1.** Weekday distributions of (a) total, (b) haemolysed and (c) EDTA-contaminated specimens and the observed/expected distribution ratios for each source (IP, GP and OP).

| | IP | GP | OP |
|---|---|---|---|
| (a) Total specimens (expected) | 27% | 61% | 12% |
| (b) Haemolysed (observed/expected) | 61% (61/27) 2.26 | 35% (35/61) 0.57 | 4% (4/12) 0.33 |
| (c) EDTA-contaminated (observed/expected) | 77% (77/27) 2.85 | 18% (18/61) 0.30 | 5% (5/12) 0.42 |

IP: inpatient; OP: outpatient.

**Table 2.** Effect of staff group on specimen haemolysis and EDTA contaminations: comparison between blood collected by phlebotomists (medical outpatient department) or by other staff (accident and emergency department) at each of hospital A and hospital B.

| | Accident and emergency | | | Medical outpatient department | | |
|---|---|---|---|---|---|---|
| Hospitals | Total specimens | Haemolysed specimens | EDTA-contaminated specimens | Total specimens | Haemolysed specimens | EDTA-contaminated specimens |
| Hospital A | 9468 | 889 (9.4%) | 30 | 3946 | 63 (1.6%) | 1 |
| Hospital B | 6672 | 745 (11.2%) | 35 | 4982 | 82 (1.6%) | 1 |

alone indicated that IP specimens exhibited disproportionately much higher rates of collection errors than those from GPs or OPs (Table 1). The effect of the staff group responsible for collecting blood was determined by comparing the total numbers of haemolysed and EDTA-contaminated specimens from the OP departments (phlebotomists) and A&E departments (other staff) of hospitals A and B, respectively (Table 2).

## Discussion

The relative rates of pre-analytical error found among blood specimens from hospital IPs far exceeded those from OPs. The reason for the difference appears to be that in this latter group, blood collection was performed exclusively and more expertly by trained phlebotomists. It could be argued that IPs represent a more challenging group and are more difficult to collect blood from, thereby exhibiting higher haemolysis rates. However, this argument does not explain the large differences in EDTA specimen contamination rates observed between patients in A&E and OPs (Table 2).

Contamination with potassium EDTA is, potentially, a far more dangerous type of collection error. Hyperkalaemia can be a medical emergency requiring urgent identification and treatment in order to avoid impending cardiac arrest. It is important to be able to accurately distinguish true from spurious hyperkalaemia. Unlike haemolysis, EDTA may only be detected by biochemical analysis. Other effects of specimen contamination by potassium EDTA anticoagulant, which are much more difficult to identify, are the masking of true hypokalaemia or hypercalcaemia, thereby delaying proper diagnosis and treatment. In some cases, true hypokalaemia may even appear as an apparently significant hyperkalaemia. No other Scottish laboratory has an EDTA assay. In laboratories that use the same blood collection system as employed in this study (six Scottish Health Boards), but do not have an EDTA assay available, then, in unsuspecting hands, the initiation of potassium lowering therapy in an already hypokalaemic individual may have a disastrous consequence.

Blood collection itself can contribute to, or be a source of, anaemia amongst IPs,[23,24] and it is particularly important to try to minimise additional and unnecessary phlebotomy episodes in the paediatric intensive care setting.[25] Additional and unnecessary phlebotomy episodes potentially increase the risk of needlestick injury for both patients and staff. Deficiencies in technique also come at a financial cost to the organisation. For example, in the current survey, the annual cost of supplies for biochemistry tests was £1.2 million. For an annual workload of 763,577 specimens, the average cost in reagents and other consumables was £1,200,000/763,577 = £1.57 per specimen. Hence, in the present survey, the total number of specimens received haemolysed ($n = 24{,}585$) or EDTA-contaminated ($n = 528$) represented a cost of approximately £40,000 per annum.

This type of survey could be replicated in other Scottish Health Boards with some benefit. Improvements in procedure whenever blood is to be

collected from IPs including those in A&E departments, in order to attempt to approach the level of expertise currently achievable by professional phlebotomists, is a training issue which could be addressed. The potentially achievable goals are improved validity of diagnostic information, reduced risk of potentially dangerous misinterpretation of results, unwanted anaemia or needlestick injury among both patients and staff, and reduction in laboratory supplies costs.

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## Declaration of conflicting interests

None declared.

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## Ethical approval

Not required.

## Guarantor

DFD

## Contributorship

DFD conceived the study, researched the literature, conducted the study and wrote the manuscript.

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