Venous versus arterial blood gas sampling in undifferentiated emergency patients

Background

In the emergency department (ED) and intensive care unit (ICU), blood gas analysis is a crucial tool in the assessment of critically ill patients (Bloom et al., 2014). Blood gas analysis is quick and repeatable at the bedside. The sampling can be done from both arterial and venous samples, with arterial samples generally considered to be more reliable and by that widely used as the standard method (Celli et al., 2004).

Arterial blood sampling (ABG) implies some risk of complications, related both to immediate side effects to a single puncture and as a result of repeated sampling. The risks involve infection, finger tang or vascular injury (Scheer, Perel, and Pfeiffer 2002). Repeated radial arterial puncturing could also lead to chronic complications such as neuropathy in the distal radial and median nerve distribution areas (Bengezi et al. 2003; Jang et al. 2012). In the worst case, this may result in sensory loss in e.g. the forefinger. In addition, arterial puncture attempts may be experienced as painful and unpleasant by the patient (Giner et al., 1996). Using local anaesthetics to minimize pain during arterial puncture only partially reduces pain (Giner et al. 2000). Arterial blood gas sampling requires skilled staff which may be limited in certain situations or regions of the world, e.g. middle and low-income countries (Shah and Department of Medicine and Pulmonology, Mata Chanan Devi Hospital, Janakpuri, New Delhi 2017).
Over the last decade, venous blood gas sampling (VBG) has gained attention as a potential alternative to ABG for investigation of the critically ill patient, with hopes of reducing the risk of complications associated with arterial sampling. Whereas parameters representing the metabolic part of acid base balance are generally considered to be equivalent and interchangeable between venous and arterial samples, the reliability of parameters defining the respiratory component is still debated (Hess and Agarwal 1992; McCanny et al. 2012). Since correctly diagnosing and correcting respiratory failure is time critical, there is a need for further research regarding the relation between arterial and venous blood samples.

Relation between arterial and venous samples
It has been clearly shown shown that venoarterial differences in values for pH, HCO_3 and Base excess (BE) lack clinical significance, though lactate levels can differ slightly if they exceed normal range values (Bloom et al. 2014; A.-M. Kelly 2016).

For the respiratory component, venous partial pressure of oxygen (pvO_2) and oxygen saturation in venous blood (SvO_2) are strongly depending on oxygen uptake in the

periphery and by that not reliable for clinical practice (Malatesha et al. 2007). For SvO_2 modern pulse oximetry can provide this information under most circumstances, provided that a good plethysmographic signal is obtained (A. M. Kelly, McAlpine, and Kyle 2001).

Venous carbon dioxide partial pressure ($pvCO_2$) represents the clinically most important parameter in respiratory evaluation of critical ill patients in the emergency department. Its reliability in relation to arterial samples is, however, questioned. Zeserson claims linear correlation for $pvCO_2$ with the corresponding arterial levels and suggests conversion is done by subtraction of a static value (Zeserson et al. 2018). This method has been evaluated in a study with 129 patients included through convenience sampling. The results of converted $pvCO_2$ showed wide confidence intervals, meaning that potentially clinically significant discrepancies in the interpretation of venous compared to arterial samples. Thus, this method is not suitable for clinical use.
Another approach is the use of a conversion model which factors in the venous partial pressure of oxygen (pvO_2) or oxygen saturation in venous blood (SvO_2). These methods show better correlation between true venous and calculated arterial pCO_2 values since pvO_2/SvO_2 act as indirect markers of oxygen uptake and strain in peripheral tissue. The suggested conversion model by Lemoël et al and Farkas appear promising, but the results have not been confirmed in other studies (Lemoël et al. 2013; EMCrit, Farkas, and Crew 2017).

As blood gas sampling is sensitive to external factors such as room air temperature, minimization of confounding factors is needed. Most previous studies lack reporting of confounding factors, although several variables associated with the sampling process and the patient's condition are known to affect the result; Time between sample-acquisition to analysis is crucial as pCO_2 and pO_2 levels change significantly due to ingress of room air (O'Connor et al. 2011). The difference in the physiological range of oxygen saturation in the radial artery in stable patients has also been shown to be clinically significant (Thorson et al. 1983; Hess and Agarwal 1992). By this, puncture site and time of venous and arterial sampling are also important factors to account for in an analysis. Further, low blood pressure, blood loss and other factors compromising circulation in acutely ill patients also make the evaluation of $vpCO_2$ more difficult (Williams et al. 2014).

Purpose/aims

Primary questions:

- How does pCO2 correlate between arterial and venous blood gas samples?
- Can a clinically reliable correlation be identified using a conversion model? (existing or new)

Secondary questions:

- How does processing times and sampling location affect the result?
- How does the patient's vital parameters (blood pressure, pulse) affect the results?
- In there a difference in the analysis results between the emergency department and the central laboratory?
- How reliable are the results beyond mild to moderate deviations from normal values in consecutive enrolled, critically ill patients?

Method

We plan to evaluate venous versus arterial blood gas analysis and the correlation between different parameters, in particular pCO2, through a prospective observational study. 250 patients deemed to be in need of arterial blood gas sampling based on their clinical condition will be included and examined by both arterial and venous blood gas sampling. We strive for consecutive inclusion of patients and enrolment will take place at all hours.

Characteristics of the study population
For enrolment, we will consider all patients who are admitted to the emergency departmentx(ambulance, walk-in etc). To be eligible, patients will need to be classified as critical ill and there has to be a clear clinical indication for an arterial blood gas sampling. Indications for arterial blood gas sampling, in turn, are primarily dictated by local SOPs (Standard Operating Procedures; "PM/ vårdprocessåtgärder") for appropriate sampling based on chief complaint, age, and vital signs upon arrival. The aim is to include these patients consecutively around-the-clock.

Inclusion criteria:

- Patients able to understand and process oral and written information and give his/her consent (within 12h), or consent provided by a close relative.
- Aged > 18 years
- Assessed to be in need of arterial blood gas analysis

Exclusion criteria:

- Unwilling to participate, or unable to understand the provided information
- Inability to give subsequently consent (> 12 hours) or unwillingness by close relative to provide consent.
- Pregnant
- Aged < 18 years

Documentation
The following parameters are documented during sampling:

- Chief complaint
- Indication for sampling
- The patient's current vital signs at the time of sampling
- Ongoing oxygen treatment (flow rate)
- Size of cannula, sampling location
- Sampling times and analysis times
- Number of puncture attempts

After sampling, the following is documented:

- Analysis results of venous and arterial blood gas sample
- Final diagnosis at discharge from the emergency department

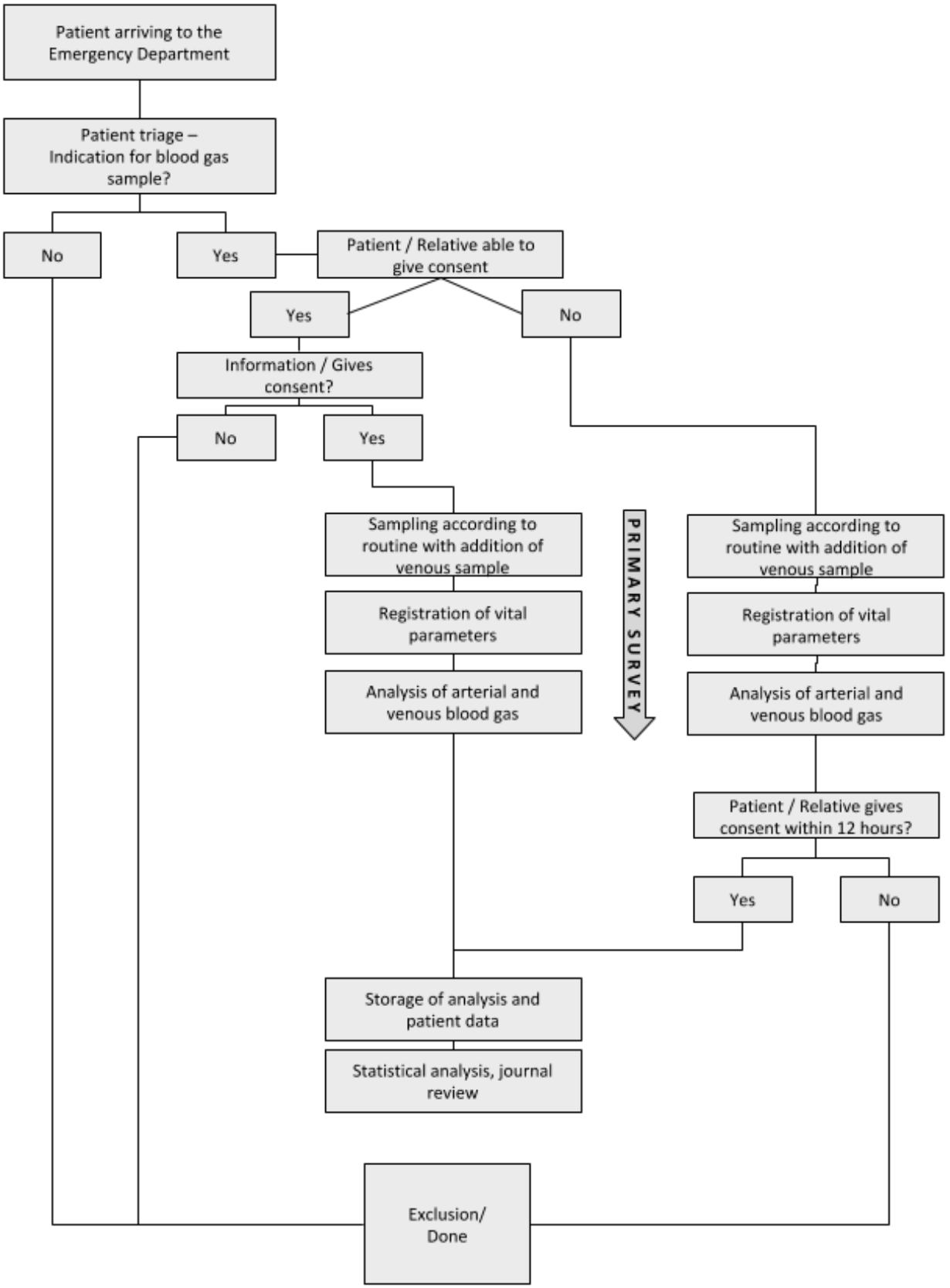
The documentation will primarily be on worksheets (see appendix), which will be marked with a patient label (name / social security number) and a serial number. The worksheet will be stored together with consent forms in a locked space of *Akutkliniken US Linköping*.
The data will be archived in the local emergency department or at the *Regional Archives in Östergötland* according to applicable laws and regulations.
The result of blood gas analysis is obtained from the digital lab system in the patient record (Lab-ROS) or directly exported from the internal memory of the analyzers at the emergency department. In both cases, the results will be used for digital compilation of study data. All electronic storage of study data will be pseudonymized by linking to patients serial number.

Practical procedures & flowchart
Patients included in this study are treated according to clinical routine. After inclusion, sampling of an arterial blood gas and a venous blood gas is performed simultaneously or as close in time as possible. Because the venous blood gas analysis sample can be taken directly from the patient's peripheral venous catheter, no additional venous puncture is usually required and the additional amount of blood that may be required is approx. 1 ml (the assay requires about 500 µl). In the very rare cases where it is not possible to establish a peripheral venous catheter within a reasonable time, the sample will be acquired from a new venous puncture together with other venous routine samples.

Sampling can be carried out by doctors or nurses. The arterial and venous blood gas analysis is performed with a blood gas analyzer in the emergency department (ABL90 Series, Radiometer Medical ApS, Bronshoj, Denmark) and is performed immediately after the sampling. Sampling times and analysis times are documented.

Survey results are routinely stored in electronic form in patient health record and also locally on the device ABL90 with social security number as ID. The data is saved for statistical analysis.

The practical process of enrolment and analysis is depicted in the following flowchart:


Patient arriving to the Emergency Department
Patient triage – Indication for blood gas sample?
No
Yes
Patient / Relative able to give consent
Yes
No
Information / Gives consent?
No
Yes
Sampling according to routine with addition of venous sample
Registration of vital parameters
Analysis of arterial and venous blood gas
PRIMARY SURVEY
Sampling according to routine with addition of venous sample
Registration of vital parameters
Analysis of arterial and venous blood gas
Patient / Relative gives consent within 12 hours?
Yes
No
Storage of analysis and patient data
Statistical analysis, journal review
Exclusion/ Done

Statistics
In previous studies, the correlation between arterial and venous samples has been evaluated using several different statistical methods:

1. T-test, Pearson's and Spearman's R variable (Zeserson et al. 2018)
2. Descriptive data are presented as mean and +/- from SD (Lemoël et al. 2013)

Our intention in this study is to make a parallel comparison of previously published methods, as well as to examine, based on collected data, whether a new formula with better precision can be derived.

The potential significance of the project

At present, arterial blood gas sampling is used as the standard procedure for assessing a critically ill patient in the emergency department.
The project aims to clarify the feasibility of replacing routine ABG sampling in the emergency department with venous punctures without impairing test results and patient care. If feasible, such a change in sampling routines could potentially mean a great improvement for patients in terms of pain and complication risks. Also, workflow and lead times in the emergency department could be improved by the fact that venous samples may be drawn by all clinical staff, whereas arterial samples are normally reserved for doctors and nurses with dedicated training.

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Patient protocol (in swedish)