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A cross-sectional study to compare two blood collection methods: direct venous puncture and peripheral venous catheter

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ABSTRACT

Objectives: To demonstrate the equivalence between blood collection methods using direct venous puncture (DVP) and a peripheral venous catheter or cannula (PVC).

Design and setting: A cross-sectional study of simple crossover design with within-subject measures carried out between October 2011 and May 2012 at a regional hospital in Spain.

Participants: 272 patients aged 18 or older hospitalised or admitted to the short-stay unit (SSU) who required laboratory testing and PVC to administer saline solution, intravenous fluid therapy and/or intravenous medication. Excluded were those with PVC collection time exceeding 20 s, difficulty of venoclysis, or who presented with arteriovenous fistula, language difficulties, in critical condition or altered consciousness with no family to consent.

Primary and secondary outcome measures: 18 variables were recorded for DVP and PVC, along with age, sex, diagnosis, vein location for DVP, location of the PVC, PVC calibre, saline syringe, intravenous fluid therapy, medication, haemolysis and clotted blood during DVP or PVC collection. Univariate analysis, Pearson's product-moment correlation coefficient (r), Lin's concordance correlation coefficient (r_c) and Bland-Altman's 95% agreement interval were provided.

Results: Included in the study were 272 patients, primarily aged 65 or older (80.9%), males (52.6%) and receiving intermittent medication (43.4%). Values obtained with both methods showed a positive linear association, being moderate for pO_2 (r=0.405) and very high for all others (r>0.86). Levels were concordant ($r_c \geq 0.9$), except for calcium (r_c=0.860), pH (r_c=0.853), pCO_2 (r_c=0.843) and pO_2 (r_c=0.336) and equivalent for all determinations except pCO_2 and pO_2, where clinically significant differences were found in more than 9% of cases (21.2%, 95% CI 16.6% to 26.5% and 73.1%, 95% CI 67.4% to 78.1%).

Conclusions: Blood collection methods using DVP and PVC can be used interchangeably for most routine laboratory tests.

Strengths and limitations of this study

- Demonstration of equivalence between blood collection methods using direct venous puncture (DVP) and peripheral venous catheter or cannula (PVC) for most routine laboratory tests.
- If the patient is already fitted with PVC or requires it shortly for administration of intravenous medication, the PVC method is preferable in order to reduce punctures.
- Only the most commonly requested laboratory tests for which differences may exist between the results for blood obtained by DVP and PVC had been analysed.

INTRODUCTION

Hospitalised patients are subjected to various invasive techniques during hospital stay. One of the most common is direct venous puncture (DVP) or phlebotomy, to obtain blood samples and be able to monitor and control their disease.

The many punctures or venoclyses, sometimes made daily, may provoke anxiety, acute pain and stress.[1 2] Moreover, they pose a risk of altered skin integrity and may degrade peripheral circulation in the upper limbs and create difficulty for reinsertion of new peripheral venous catheters or cannulas (PVC) of about 3–5 cm in length for administration of intravenous medication necessary when phlebitis or extravasations occur that require removal of the affected catheters and circulatory treatment for venous insufficiency.

Obtaining blood samples using PVC would improve treatment quality while reducing use of traumatic techniques and risk to the nursing staff of accidental needlestick injuries.

Professional staff requesting laboratory testing at the hospital where this study was conducted usually preferred collection using DVP, although the patient was already fitted with PVC. PVC may be used according to the criteria of the nursing staff and the test to be performed, as no protocol or guide concerning PVC collection exists. In this hospital, PVC is being changed once every 3 days, and

every 2 days if inserted in an emergency room due to infection risk.

Various studies have been conducted without finding differences between the laboratory results obtained with DVP and central venous catheters[3 4] or arterial catheters.[5] However, comparisons of blood collection using PVC and DVP have been little studied.

This study aimed to analyse linear association, concordance and equivalence between blood collection methods using DVP (control) and PVC.

METHODS

Design and setting

A cross-sectional study of simple crossover design using within-subject measures carried out between October 2011 and May 2012 at the Hospital de Palamós, a reference hospital in the Baix Empordà region. The hospital has 100 beds and assists a large floating population including 10 000 hospitalisations, 57 000 emergencies and 152 892 laboratory requests (12 206 from the inpatient ward) annually.

Study population and sample

Participants studied were aged 18 years or older, admitted to the inpatient ward or emergency services short-stay unit (SSU) and required laboratory studies; all of them were fitted with PVC to administer saline solution, intravenous fluid therapy and/or perfusion or intermittent intravenous medication.

Excluded were participants with PVC collection time exceeding 20 s, difficulty of venoclysis, or who presented with arteriovenous fistula and language difficulties, which made it impossible to comprehend the informed consent, in critical condition or altered state of consciousness with no family to consent.

The minimum sample size was calculated assuming a 5% risk and an 80% potential for detecting a minimal clinically significant difference between DVP and PVC indicated for each laboratory test, standards which were agreed by the research team and all laboratory, internal medicine and emergency medicine medical staff. The SD of the differences between each determination was estimated using a pilot study of 100 patients. The minimum sample size required was 111 participants. Finally, 272 participants were included from the pilot study and those other patients who met the defined selection criteria.

Data collection instruments and procedure

Information was collected via the hospital's electronic health records and a specific survey for the study, with variables recorded in an Excel database.

One blood sample was extracted for each laboratory test using DVP and another using PVC with an interval under 5 min between them according to a randomised collection sequence. Samples were placed in a tube with individual identification numbers and were simultaneously sent under the same laboratory conditions. Collections were performed during normal hours for these tests by two nurses who were part of the investigational team with a 10 mL Luer syringe and a 21 gauge intravenous needle. Collection using DVP was made from the limb opposite to the one with the PVC. For PVC collection, the intravenous fluid therapy line was first closed for 15 s, as was any medication with the PVC three-way valve, and a syringe was adapted, from which 4 mL of blood was discarded, as recommended in recent studies.[6 7] Thereafter, the syringe was changed by rotating the valve 1/8 to complete removal. Finally, the venous access was washed with 4 mL of saline solution and intravenous fluid therapy and/or any perfusions were restarted. If clotted blood was detected, the sample was rejected and a new blood collection was performed.

Variables

The dependent variables chosen were the most frequently requested tests for which differences may exist between the laboratory results for blood obtained by DVP and PVC. Each variable was recorded for both collection methods; for biochemistry: amylase (U/L), calcium (mg/dL), total cholesterol (mg/dL), creatinine (mg/dL), creatine kinase (U/L), basal glucose (mg/dL), aspartate aminotransferase (SGOT) (U/L), potassium (meq/L), sodium (meq/L) and urea (mg/dL); for haematology: red blood cells (10^6/µL), haemoglobin (g/dL), leucocytes (10^3/µL), platelets (10^3/µL) and prothrombin ratio (%); and for blood gas: venous blood acidity (pH), venous carbon dioxide partial pressure (pCO_2) (mm Hg) and venous oxygen partial pressure (pO_2) (mm Hg).

For descriptive purposes, the variables considered and assessed at the time of blood collection were age in years (<65, ≥65), sex, diagnosis, vein insertion of the DVP and PVC (hand, wrist, forearm, inner arm), PVC calibre in gauges (14, 16, 18, 20, 22, 24) and whether saline syringe, intravenous fluid therapy (saline solution, 5% glucose solution, glucosaline solution, isoplasmal and/or Ringer's solution), perfusion and/or intermittent medication, haemolysis and clotted blood during DVP or PVC collection were used.

Statistical analysis

Univariate descriptive analysis was performed using frequencies for the categorical variables and the mean, SD and quartiles for continuous variables.

Bivariate descriptive analysis included Student t test to analyse differences according to the collection sequence. Pearson's product-moment correlation coefficient (r)[8] and Lin's concordance correlation coefficient (r_c)[9–11] were provided for assessing linear association and absolute agreement between the two methods, respectively.

For equivalence analysis, the Bland-Altman agreement interval for 95%[12–14] was calculated for each variable as was the mean difference between methods±1.96 SD of the difference. If the result was within the clinically

accepted interval, defined by the minimum clinically significant difference (as defined by the researcher) comparing DVP and PVC, the methods were considered equivalent.

The CI for estimating proportions was calculated using Wilson's score method.[15 16]

The confidence level was deemed to be 95% and the IBM program SPSS Statistics V.21 for Windows[17] was used.

Ethical considerations

The study was conducted in accordance with current European and Spanish laws on ethics in research.[18] Informed consent was obtained from each study participant and the confidentiality of all data was ensured. The study protocol was approved by the research committee of the Serveis de Salut Integrats Baix Empordà organisation.

RESULTS

In the study, 17 patients were excluded for the following reasons: 5 with PVC collection time exceeding 20 s (29.4%), 7 with difficulty of venoclysis (41.2%), 1 with arteriovenous fistula (5.9%) and 4 with altered state of consciousness with no family to consent (23.5%).

A total of 272 patients were included, primarily aged 65 or older (80.9%), males (52.6%) and with cardiorespiratory diagnoses (40.1%). The location of the vein for puncture (95.6%) and catheter (44.5%) was usually the inner arm. Mostly 20 calibre intravenous catheters were used (74.3%) without a saline syringe (82.0%) but with intravenous fluid therapy (70.6%), glucosaline solution (34.6%) and intermittent medication (43.4%). Haemolysis occurred in 10 samples (3.7%) on collection using PVC. Clotted blood occurred in two samples (0.7%) and in one sample (0.4%) during DVP and PVC collection, respectively (table 1).

Laboratory findings did not show any differences related to collection sequence between both methods. Positive linear association was observed which was moderate for pO_2 (r=0.405) and very high for all other values (r>0.86).

Concordance was low for calcium and blood gas levels (r_c<0.90), and particularly low for pO_2 (r_c=0.336). It was moderate for potassium, sodium and prothrombin ratio (0.90≤r_c≤0.95); substantial for cholesterol, creatinine and basal glucose (0.95<r_c≤0.99); and nearly perfect for all other biochemistry levels: amylase, creatine kinase, aspartate aminotransferase and urea (r_c>0.99).

Collection methods were shown to be equivalent for 10 of the 18 variables studied using the Bland-Altman method: calcium, creatinine, aspartate aminotransferase, potassium, sodium, red blood cells, haemoglobin, leucocytes, platelets and pH. Clinically significant differences were found for the two remaining determinations: pCO_2 (21.2%, 95% CI 16.6% to 26.5%) and pO_2 (73.1%, 95% CI 67.4% to 78.1%) in more than 9% of cases (table 2).

DISCUSSION

Laboratory tests are necessary for people who are hospitalised or who require urgent care. Routine analyses are requested on admission to the internal medicine department and several times daily in units such as the SSU, intensive care unit (ICU) and coronary unit. Patients often have a PVC inserted, meaning it would be best to

Table 1 Description of the study population at the time of collection by direct venous puncture and peripheral venous catheter (n=272)

Variable	n	Per cent	95% CI
Age (years)			
≥65	220	80.9	(75.8 to 85.1)
Sex			
Male	143	52.6	(46.6 to 58.4)
Diagnosis			
Cardiorespiratory	109	40.1	(34.3 to 46.0)
Cerebrovascular	14	5.1	(3.1 to 8.5)
Gastrointestinal	68	25.0	(20.2 to 30.5)
Genitourinary	28	10.3	(7.2 to 14.5)
Osteomuscular	29	10.7	(7.5 to 14.9)
Other	24	8.8	(6.0 to 12.8)
Vein location for DVP			
Hand	2	0.7	(0.2 to 2.6)
Wrist	4	1.5	(0.6 to 3.7)
Forearm	6	2.2	(1.0 to 4.7)
Inner arm	260	95.6	(92.4 to 97.5)
Location of the PVC			
Hand	17	6.3	(3.9 to 9.8)
Wrist	68	25.0	(20.2 to 30.5)
Forearm	66	24.3	(19.6 to 29.7)
Inner arm	121	44.5	(38.7 to 50.4)
PVC calibre (gauges)			
16	2	0.7	(0.2 to 2.6)
18	50	18.4	(14.2 to 23.4)
20	202	74.3	(68.8 to 79.1)
22	18	6.6	(4.2 to 10.2)
Saline syringe			
No	223	82.0	(77.0 to 86.1)
Intravenous fluid therapy*	192	70.6	(64.9 to 75.7)
Saline solution	85	31.3	(26.0 to 37.0)
5% Glucose solution	45	16.5	(12.6 to 21.4)
Glucosaline solution	94	34.6	(29.2 to 40.4)
Isoplasmal	9	3.3	(1.8 to 6.2)
Ringer's	1	0.4	(0.1 to 2.1)
Medication*			
Perfusion	24	8.8	(6.0 to 12.8)
Intermittent	118	43.4	(37.6 to 49.3)
Haemolysis during DVP collection			
Yes	0	0.0	(0.0 to 1.4)
Haemolysis during PVC collection			
Yes	10	3.7	(2.0 to 6.6)
Clotted blood during DVP collection			
Yes	2	0.7	(0.2 to 2.6)
Clotted blood during PVC collection			
Yes	1	0.4	(0.1 to 2.1)

*Non-exclusive categories.
DVP, direct venous puncture; PVC, peripheral venous catheter.

Table 2 Linear association, concordance and equivalence between the findings obtained by direct venous puncture and peripheral venous catheter

					Clinically accepted interval				Agreement interval			
Determination	**Variable**	**N**	**r**	**r_c**	**CAI**	**n**	**Per cent**	**95% CI**	**95% AI**	**n**	**Per cent**	**95% CI**
Biochemistry	Amylase (U/L)	265	0.999	0.996	(−20 to −20)	1	0.4	(0.1 to −2.1)	(−34.09 to −36.10)	1	0.4	(0.1 to −2.1)
	Calcium (mg/dL)	266	0.899	0.860	(−1 to −1)	2	0.8	(0.2 to −2.7)	(−0.90 to −0.44)	7	2.6	(1.3 to −5.3)
	Total cholesterol (mg/dL)	269	0.984	0.983	(−10 to −10)	12	4.5	(2.6 to −7.6)	(−13.64 to −15.56)	6	2.2	(1.0 to −4.8)
	Creatinine (mg/dL)	271	0.982	0.982	(−0.3 to −0.3)	4	1.5	(0.6 to −3.7)	(−0.25 to −0.27)	4	1.5	(0.6 to −3.7)
	Creatine kinase (U/L)	262	0.999	0.999	(−20 to −20)	13	5.0	(2.9 to −8.3)	(−28.76 to −25.49)	9	3.4	(1.8 to −6.4)
	Basal glucose (mg/dL)	272	0.960	0.957	(−15 to −15)	17	6.3	(3.9 to −9.8)	(−34.69 to −26.66)	9	3.3	(1.8 to −6.2)
	Aspartate aminotransferase (SGOT) (U/L)	269	0.998	0.998	(−10 to −10)	7	2.6	(1.3 to −5.3)	(−8.86 to −7.47)	11	4.1	(2.3 to −7.2)
	Potassium (mEq/L)	269	0.937	0.936	(−0.4 to −0.4)	19	7.1	(4.6 to −10.8)	(−0.45 to −0.45)	13	4.8	(2.8 to −8.1)
	Sodium (mEq/L)	271	0.950	0.950	(−4 to −4)	4	1.5	(0.6 to −3.7)	(−2.63 to −3.11)	12	4.4	(2.6 to −7.6)
	Urea (mg/dL)	269	0.997	0.997	(−5 to −5)	9	3.3	(1.8 to −6.2)	(−6.65 to −6.94)	7	2.6	(1.3 to −5.3)
Haematology	Red blood cells (10^6/μL)	268	0.988	0.988	(−0.5 to −0.5)	3	1.1	(0.4 to −3.2)	(−0.22 to −0.22)	12	4.5	(2.6 to −7.7)
	Haemoglobin (g/dL)	268	0.986	0.986	(−0.6 to −0.6)	9	3.4	(1.8 to −6.3)	(−0.65 to −0.65)	8	3.0	(1.5 to −5.8)
	Leucocytes (10^3/μL)	268	0.983	0.983	(−2 to −2)	4	1.5	(0.6 to – to 3.8)	(−1.78 to −1.75)	5	1.9	(0.8 to −4.3)
	Platelets (10^3/μL)	267	0.982	0.982	(−50 to −50)	3	1.1	(0.4 to −3.3)	(−30.32 to −34.37)	7	2.6	(1.3 to −5.3)
	Prothrombin ratio (%)	269	0.918	0.917	(−7 to −)	22	8.2	(5.5 to −12.1)	(−16.63 to −19.14)	5	1.9	(0.8 to −4.3)
Blood gas	Venous carbon dioxide potential (pH)	260	0.862	0.853	(−0.1 to −0.1)	2	0.8	(0.2 to −2.8)	(−0.06 to −0.04)	11	4.2	(2.4 to −7.4)
	Venous carbon dioxide partial pressure (pCO_2) (mm Hg)	260	0.875	0.843	(−5 to −5)	55	21.2	(16.6 to −26.5)	(−6.14 to −10.51)	10	3.8	(2.1 to −6.9)
	Venous oxygen partial pressure (pO_2) (mm Hg)	260	0.405	0.336	(−5 to −5)	190	73.1	(67.4 to −78.1)	(−40.60 to −22.08)	10	3.8	(2.1 to −6.9)

N, Number of tests with valid findings for direct venous puncture (DVP) and peripheral venous catheter (PVC); n, Number of tests showing differences between DVP and PVC greater than the interval; r, Pearson's product-moment correlation coefficient; r_c, Lin's concordance correlation coefficient; CAI, interval defined by the minimal clinically significant difference (according to investigators) between DVP and PVC; 95% AI, interval of agreement of 95% according to the Bland-Altman method: mean difference between methods±1.96 SD of the difference; 95% CI, CI of 95% for proportion according to the Wilson score method.

be able to collect samples by this method if no differences exist in comparison to the DVP method.

Several studies have analysed the concordance between the laboratory values obtained using DVP and PVC, most using PVCs fitted with saline syringes.[6 7] However, their equivalence has been little studied, sometimes with inadequate methodology, by contrasting means testing or the correlation coefficient,[19] and at other times using a small sample size.[20 21]

This study showed concordance between the methods used for the variables studied except for calcium and blood gas levels; and equivalence except for pCO_2 and pO_2. The same results were obtained in a study by Hambleton *et al*,[22] although concordance for calcium was moderate in that study as analysed using the intraclass correlation coefficient.

However, a study by Berger-Achituv *et al*[23] showed that DVP and PVC results were not equivalent for glucose, although that study was performed on children and only 2 mL of blood were discarded before collection. A study by Zlotowski *et al*[20] also did not show equivalency for glucose, potassium and bicarbonate (not analysed in our study). Potassium level is the laboratory value most vulnerable to sample haemolysis, which was found to be higher when obtained using PVC, although the two methods were found to be equivalent as observed in a study by Kennedy *et al*.[24]

The equivalency found in our study between the methods for blood collection studied could suggest the use of PVC in patients who are bleeding and/or have infectious diseases, cases for which requests for new haemograms are common. Although our study analysed the prothrombin ratio, others, such as those of Zlotowski *et al*[20] and Zengin *et al*,[25] used prothrombin time, finding equivalency and no difference in mean between the methods.

The non-equivalency of pCO_2 and pO_2 levels found in the two methods may be due to handling following collection, during transfer of the blood from the Luer syringe to the blood gas syringe or to the time elapsed before samples were analysed. Contact with air causes changes in pO_2, and hence the importance of not handling the syringe and of it being filled with the correct amount of blood and excess air removed.

Calcium values obtained with both collection methods had a positive linear association and were equivalent but low concordant. This could be because while in the case of PVC trauma of the puncture was long before the time of blood collection, in DVP this immediate trauma can cause removal of tissue factors and so activate the coagulation process lightly and increase calcium intake.

Our study has some limitations. On the one hand, the laboratory tests chosen were the most frequently requested for which differences may exist between the results for blood obtained by DVP and PVC. So the study results may not be generalisable to all laboratory tests. On the other hand, it would have been beneficial to register the lasting of venesection and not exclude subjects with collection time exceeding 20 s in order to recognise its effect on the studied parameters. Moreover, laboratory tests that were conducted in the study were not standardised.

Blood extraction methods using DVP and PVC can be considered to be equivalent for the variables studied except regarding pCO_2 and pO_2. With proper syringe handling, they may be used interchangeably.

Elderly population mainly experiences more pain and discomfort with multiple direct venepunctures due to difficult veins, especially if they are performed by professional staff who are non-specialist nurses or non-expert. If the patient is already fitted with PVC or requires it shortly for administration of intravenous medication, the PVC method is preferable in order to reduce punctures, although it is more expensive than the DVP method. Thereby, the patient benefits considerably[26 27] from lack of pain caused, reduced risk of peripheral neurovascular dysfunction and improved limb surveillance and safety. In other cases, if the patient is not fitted with a cannula and requires a blood collection, the DVP method would be preferable because fitting an unnecessary cannula has drawbacks such as infection risk, phlebitis, cellutitis, haemolysis or clotted blood.

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Contributors NO-A coordinated and designed the study, interpreted the results and drafted the paper. IS-P designed the study, performed and interpreted the statistical analysis and drafted the paper. TB-P and MD-B performed the blood collections. TB-P, MD-B and MP-M acquired, cleaned and interpreted the data and contributed to the write-up. All authors critically revised the paper and are guarantors.

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Patient consent Obtained.

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