

# The influence of COVID-19 disease on pre-analytical blood sample haemolysis rates in three acute medical units: an interrupted time series analysis

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## ARTICLE INFO

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### **Key words:**

COVID-19 disease, pre-analytical,  
haemolysis, interrupted time series

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## ABSTRACT

The COVID-19 pandemic impacted delivery of health services. The aim of our study was to determine the impact of COVID-19 disease on pre-analytical blood sample haemolysis by modelling the daily haemolysis rates variations pre and post COVID-19 infections. Ethics approval was obtained prior to study commencing.

Interrupted Time Series data analysis was conducted on UK National Health Service Acute Admissions Unit 25-month (1 February 2019 to 28 February 2021) biochemistry (total and haemolysed) blood sample dataset. Interruption was set on 23 March 2021, the start of the first UK lockdown. Daily haemolysis rate (% samples haemolysed) data were fitted with a spline curve to determine influence of haemolysis rates on short or medium-term temporal trends.

Linear regression was performed so as to determine long-term temporal trends pre- and post-intervention.

There were 32,316 biochemistry blood sample results: 19,058 pre and 13,258 (342 days) from the post-intervention period. Overall median daily haemolysis rate was 7.3% (range: 0-30.6%), 7.7% pre-intervention versus 6.5% post-intervention ( $p < 0.0001$ ). The proportion of haemolysis cases negatively correlated with the number of samples processed ( $\rho = 0.09$ ;  $p = 0.01$ ). The pre-intervention slope was  $-1.70\% \cdot y^{-1}$ , y intercept 9.04%; post-intervention slope was  $-1.88\% \cdot y^{-1}$ , y intercept was 10.2%; with no difference in either the slope ( $p = 0.87$ ) or intercept ( $p = 0.16$ ).

There was no association between short-term variation in haemolysis rates with changes in practice due to COVID-19 disease and the disease itself. The negative correlation between haemolysis rate and the number of samples processed highlights the importance of continued venepuncture practice to facilitate haemolysis rate reduction.



## INTRODUCTION AND BACKGROUND

COVID-19 disease is a novel severe acute respiratory syndrome caused by coronavirus 2 (1). The disease was first reported in Wuhan, China, where pneumonia cases of unknown aetiology were observed (2). The preliminary epidemiological investigations confirmed that sufferers were mostly people that worked at or were handlers and frequent visitors to the Huanan Seafood Wholesale (2). The first UK COVID-19 cases were identified in the North of England on the 29 January 2020 with confirmed COVID-19 infection reported on 31 January 2020 (3). On the 30 January 2020, the World Health Organisation declared this disease as a public health emergency of international concern (2).

This implied that the infection would affect global health security and required an international coordinated response (4). As the infection continued to spread throughout the world, the virus started to mutate. For example, the identification of the Alpha (previously known as Kent) variant was made, through viral genomic sequencing, on 14 December 2020 (5). Figure 1 summarises the timeline of the infection from China to the UK during the study period.

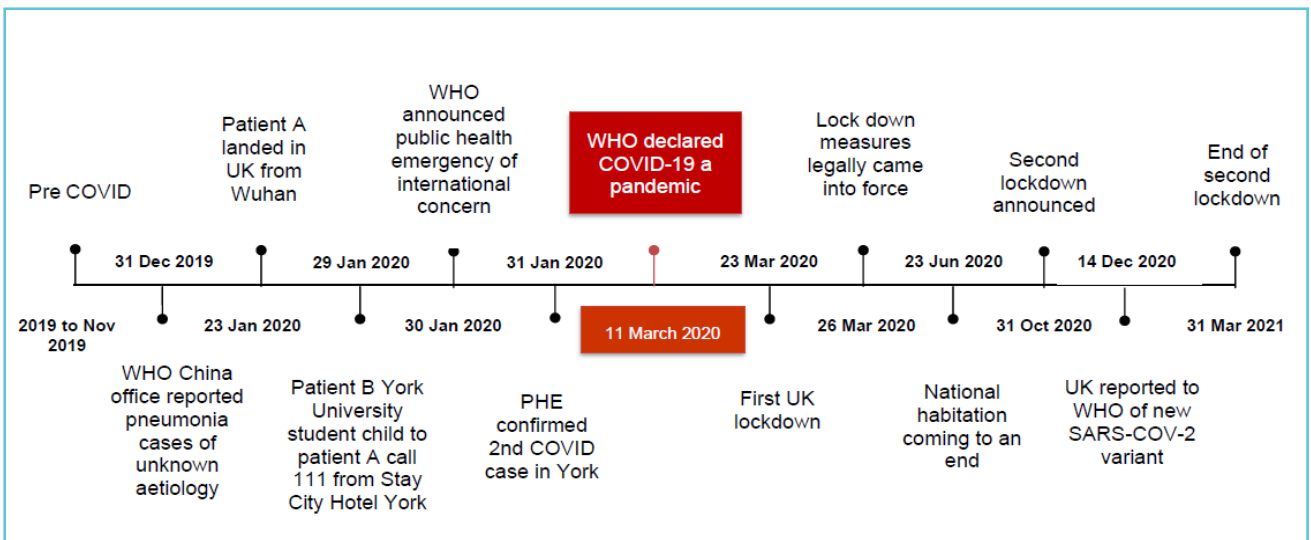
## COVID-19 DISEASE

COVID-19 affects the respiratory and the immune systems (6). In severe disease, other organs such as the heart and kidneys are affected (4). Renal failure can result when kidneys are affected (6). Hypercoagulability, acute myocardial injury and myocarditis, arrhythmias, and acute coronary syndromes can follow if the heart is affected (7). Associated abnormal blood tests have also been reported in patients with COVID-19 on admission to hospital (8). Some of the blood results have indicated coagulation abnormalities and organ dysfunction (4). These have included decreased lymphocyte count, prolonged prothrombin time, increased D-dimer level, or increased aspartate aminotransferase, creatinine, creatine kinase, and lactate dehydrogenase (4). However, gradual drop in haemoglobin levels have also been identified in some cases and have been confirmed as Autoimmune Haemolytic Anaemia secondary to COVID-19 Disease (8; 9).

## BIOCHEMICAL ANALYSIS

All routine biochemical analysis including the measurement of potassium and the determination of the haemolysis index was performed using the Siemens Advia 2400XPT and Atellica CH930 analysers (Siemens Healthcare Ltd, Camberley, UK). Haemolysis is assessed by diluting 5 $\mu$ L of specimen in 0.9% saline and measuring the absorbance at

**Figure 1** UK COVID-19 infection timeline.  
The timeline summarises COVID-19 related events in the UK from pre-COVID period to end of the study, February 2021.



571 and 596nm. The assessment of haemolysis was performed whenever any serum specimen was analysed, with the level of haemolysis being determined as being either negative or positive, with positive results flagged as “+”, “++”, “+++” or “++++”. The positive haemolysis flags equate to cut-off values for haemoglobin of 45, 140, 235 and 445 mg/dL respectively. In routine practice, and for the purposes of this study, any specimen with a haemolysis flag of “+” or above was considered to be haemolysed and as such the numerical potassium result was not reported.

### RATIONALE FOR THE RESEARCH

Autoimmune haemolytic anaemia is a rare autoimmune disorder characterised by autoantibodies that react with self-red blood cells and result in their destruction (8). Cases of autoimmune haemolytic anaemia in patients with COVID-19 have been reported in literature (8; 9; 10). This is an atypical presentation of COVID-19 that may occur during the period of infectivity (9). Nevertheless, patients with respiratory

diagnosis had significantly higher (52.9%) haemolysis rate than patients with other diagnoses (11). The haemolysis rate in patients with respiratory diagnosis was second highest (16.7%) compared to 18.6% in patients with neurological diagnosis (12). The disease process and acuity of the patients at time of presentation to the hospital may be the associated factors to sample haemolysis. High haemolysis rate in patients with poor venous access such as those dehydrated have previously been reported (11). A total of 114,463,420 people worldwide were infected by COVID-19; and 2,557,524 deaths were reported by end February 2021 (2).

Older people are commonly most affected by COVID-19 infection (2). Comorbidities and low immune status could be the most common explanations for the vulnerability in this age group. Hypertension and diabetes are amongst the commonly reported risk factors for severe COVID-19 disease (7). Significantly high rates of haemolysis were reported in individuals aged 63 and above (11). The highest haemolysis rate (24%) was reported in individuals of

age 95 years and above (13). Factors such as severe COVID-19 disease, multi-organ failure and dehydration amongst the individuals with COVID-19 disease, could lead to hypovolaemia. These characteristics could in turn lead to difficulties in performing venepuncture and result in the venepuncture being performed in the smaller veins distal to the recommended antecubital fossa veins (14). Furthermore, the risk of infection amongst the staff taking care of patients with COVID-19 disease could also lead to such practice in individuals with poor venous access.

### AIM AND RESEARCH QUESTIONS

The aim of this study was to investigate the influence of COVID-19 disease on pre-analytical blood sample haemolysis rate in three front of house acute admissions units (Clinical Decisions Unit, Acute Medical Unit and Acute Assessment Unit) and in one North East England National Health Service Trust. Research questions were designed as a guide to achieving the aim.

#### Research questions

1. Did the peak period of COVID-19 disease in the UK have any influence on the pre-analytical blood sample haemolysis rate?
2. Did any factors, such as age, interact with any COVID-19 influence on pre-analytical blood sample haemolysis rate?

### HYPOTHESIS

The hypothesis to the study is based *a priori* on COVID-19 infection literature (8; 9; 10) and on previous relevant literature on haemolysis rate and respiratory infection (11; 12). The hypothesis is that there will be a temporary increase in pre-analytical blood sample haemolysis secondary to COVID-19 disease. Once the infection rates drop, haemolysis rates will revert to the pre-COVID-19 levels.

### METHODS

Interrupted Time Series design was used to investigate the impact of COVID-19 disease (intervention) on pre-analytical blood sample haemolysis. A 25-month dataset (1 February 2019 to 28 February 2021) of biochemistry blood sample (total and haemolysed) was used in the analysis. Time series is a continuous sequence of observations on a population taken repeatedly over time (15). Interrupted Time Series works best with short term outcomes that are expected to change either relatively quickly after an intervention is implemented or after a clearly defined lag (15). The uncertainty of the impact of COVID-19 disease on pre-analytical blood sample haemolysis and the novelty of the infection meant that the design is appropriate. Ethics approval obtained from the Teesside University Health and Social Care Ethics subcommittee, under an Ethics Release format and from the local Trust Research Ethics and Development team. The study preparation and release of followed General Data Protection Act (GDPA) regulations.

### DATA COLLECTION

Biochemistry blood results with the following specifications, were obtained through the Laboratory Information Management System:

- biochemistry blood sample results for potassium (total and haemolysed),
- results from the three front of house units of Clinical Decisions Unit, Acute Assessment Unit and Acute Medical Unit of the local National Health Service Foundation Trust,
- results from the samples collected from 1 February 2019 to 31 January 2020,
- and from 1 February 2020 to 28 February 2021.

Virology reverse-transcriptase polymerase chain reaction or lateral flow test results were not

requested for the study due to them not being available for all patients being admitted to hospital earlier in the pandemic. Some incidental diagnoses were made through chest x-rays and computerised tomography scans. Such variability in reaching the diagnosis made it impossible for x-ray and scan results to be included in the requested dataset. However, the Acute Assessment Unit was set aside for potential and confirmed COVID-19 cases. Therefore, a comparison of haemolysis rate by diagnosis was made based on this knowledge.

## **DATA ANALYSIS**

A 25-month dataset of biochemistry blood results collected from the three front of house units of a local Trust was used in the data analysis. The blood results were from pre and post COVID-19 infection (after first UK lockdown). The interruption was defined as the start of the first UK lockdown, 23 March 2020. The pre-intervention phase (before COVID-19 infection) was set from 1 February 2019 to 22 March 2020. The post intervention (after COVID-19 infection) was set from 24 March 2020 to 28 February 2021.

The blood results were uploaded into Excel and checked for completeness (e.g., sample collected, and results released date and the results). Descriptive data analysis was performed to summarise patterns and trends in the data (15). These included measures of central tendency (mean, median, and measures of variance such as range, minimum and maximum and percentile). The daily, weekly, fortnightly, and monthly haemolysis rate proportions were analysed in Excel. Thereafter, the data was imported in GraphPad Prism software for further analysis. The main aim was to model the daily variations in pre-analytical haemolysis rates pre and post COVID-19 infections. 'The day' was the main unit of analysis with the time points

based on the day of the release of test results as opposed to the blood sample collected day. Test of normality (Kolmogorov-Smimov) was performed to determine the characteristic of the data prior to further statistical analysis. The outcome was haemolysis rate pre (coded 0) and post (coded 1). Kruskal-Wallis test was used to determine the proportion of haemolysis cases affected by the day of the week. Mann Whitney U test was applied to compare haemolysis rate pre and post COVID-19. Spearman correlation test was performed to determine the association between haemolysis rate and the number of samples processed. Paired t-test was then performed to compare the mean haemolysis rate pre and post COVID-19 infection with significance level set at 0.05.

To establish whether haemolysis rates were influenced by short- or medium-term temporal trends, the data were fitted with a spline curve, which is a number of different polynomial curves that are joined smoothly end-to-end to cover the full period (16). In generating the spline curve, it is necessary to decide how many 'knots' (join-points) there should be, which governs how many end-to-end curves will be used and therefore how flexible the curve will be. If there are too few knots, the spline curve will be a poor fit, and fail to capture the main long-term patterns closely; whereas too many knots will result in a spline curve which fits short-term trends too closely, preventing further analysis of these trends. In our case, the long-term data were best described by 25 knots. Linear regression was then performed pre- and post-intervention to determine whether there were long-term temporal trends in haemolysis rates.

## **RESULTS**

A total of 32,316 biochemistry blood samples were reported from the three acute admissions units during the study period. Of which 19,058

were from the period prior to the 23 March 2020 lockdown, pre intervention (1 February 2019 to 22 March 2020) and 13,258 from the post intervention period (24 March 2020 to 28 February 2021). There were 16,271 blood samples results in 2019, 14,196 in 2020, and 1,849 in January and February 2021. A total of 351 blood results were excluded due to missing or results labelled 'old'.

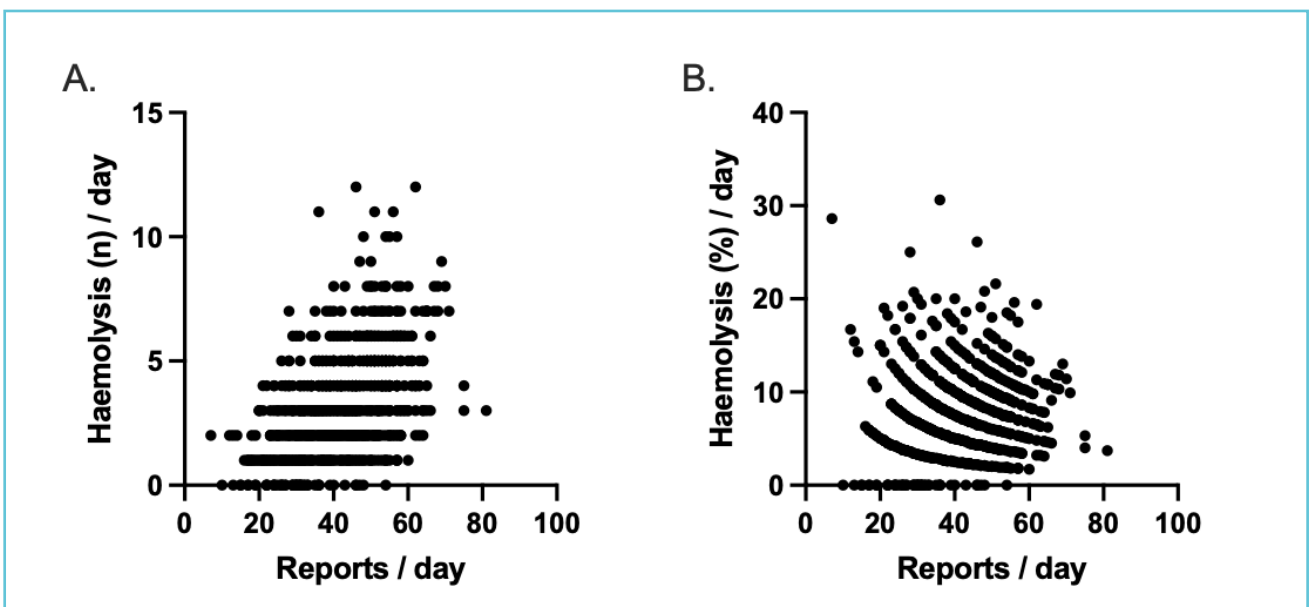
There were only 3 days (26 to 28 February 2021) in the final week of the study, the data in that week was omitted in the analysis of fortnightly trends. The number of results recorded per day ranged from 7 to 81 (mean: 43), with more test results before the intervention (median, per day: 50, range: 18-81) than after the intervention (median, per day: 34.5, range: 7-60) (Mann Whitney *U* test,  $p < 0.0001$ ). The number of haemolysed cases reported per day positively correlated with the number of samples processed (Spearman correlation;  $\rho = 0.50$ ;  $p < 0.0001$ ) (Figure 2A), while the proportion of haemolysis cases negatively correlated with the number

of samples processed (Spearman correlation;  $\rho = 0.09$ ;  $p = 0.01$ ) (Figure 2B).

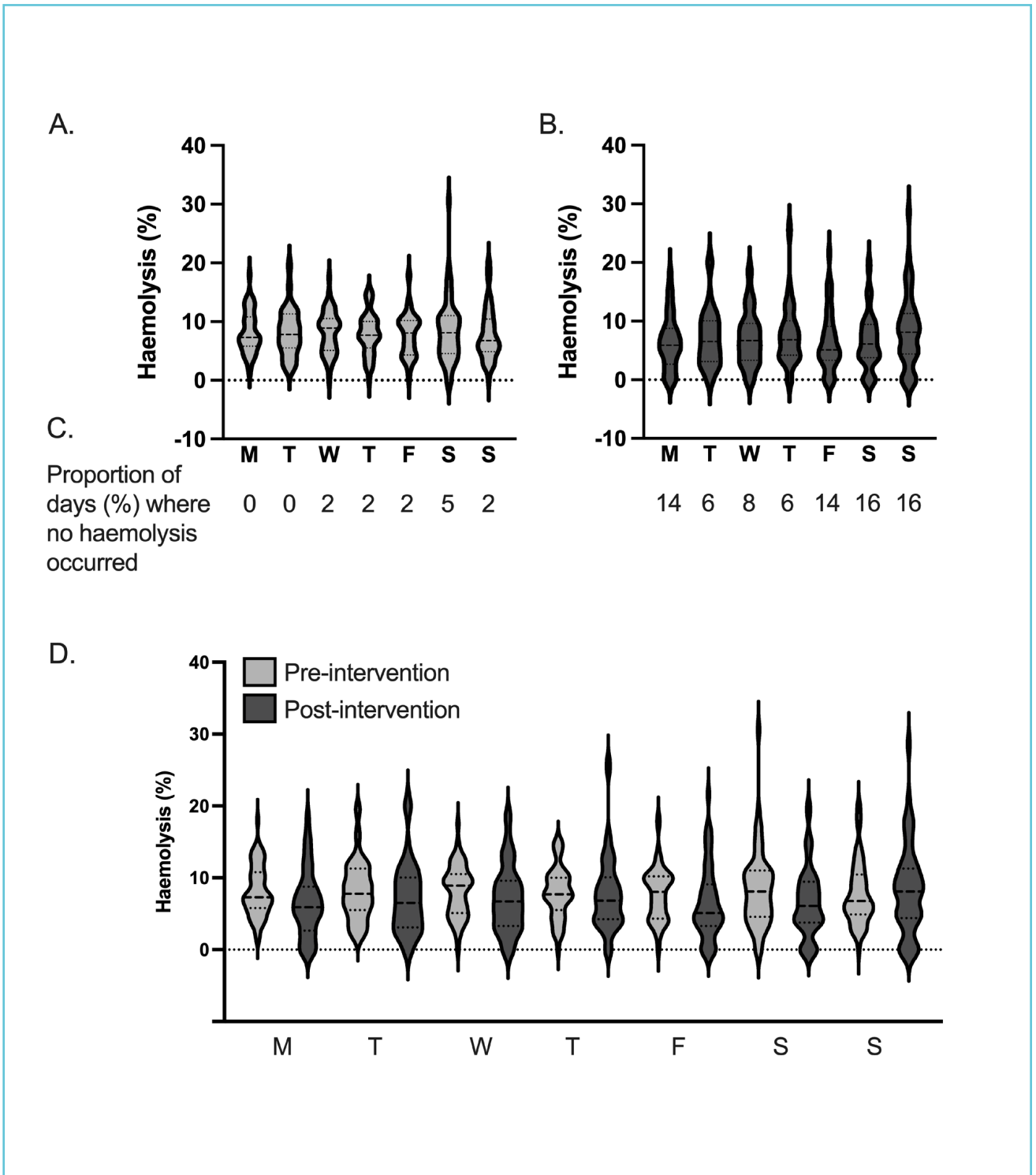
There were 416 time points in the pre-intervention phase and 342 time points in the post intervention phase. The proportion of haemolysis cases was not affected by the day of the week pre-intervention (Kruskal-Wallis,  $p = 0.96$ ), Figure 3A; or post-intervention (Kruskal-Wallis,  $p = 0.59$ ), Figure 3B. Combined results of 3A and B are presented in Figure 3D and proportions of days with number of haemolysed samples presented in 3C.

The overall median daily haemolysis rate during the entire period (1 February 2019 – 28 February 2021) was 7.3% (range: 0-30.6%). The median daily haemolysis was lower post-intervention: the pre-intervention rate was 7.7% (range: 0-30.6%), compared to 6.5% (range: 0-28.6%) post-intervention (Mann Whitney *U* test,  $p < 0.0001$ ). Daily, weekly, fortnightly and monthly haemolysis rates are presented in Figures 4A, B, C and D, respectively. The January 2019 to February 2021 daily collected haemolysed samples and rates are available upon request.

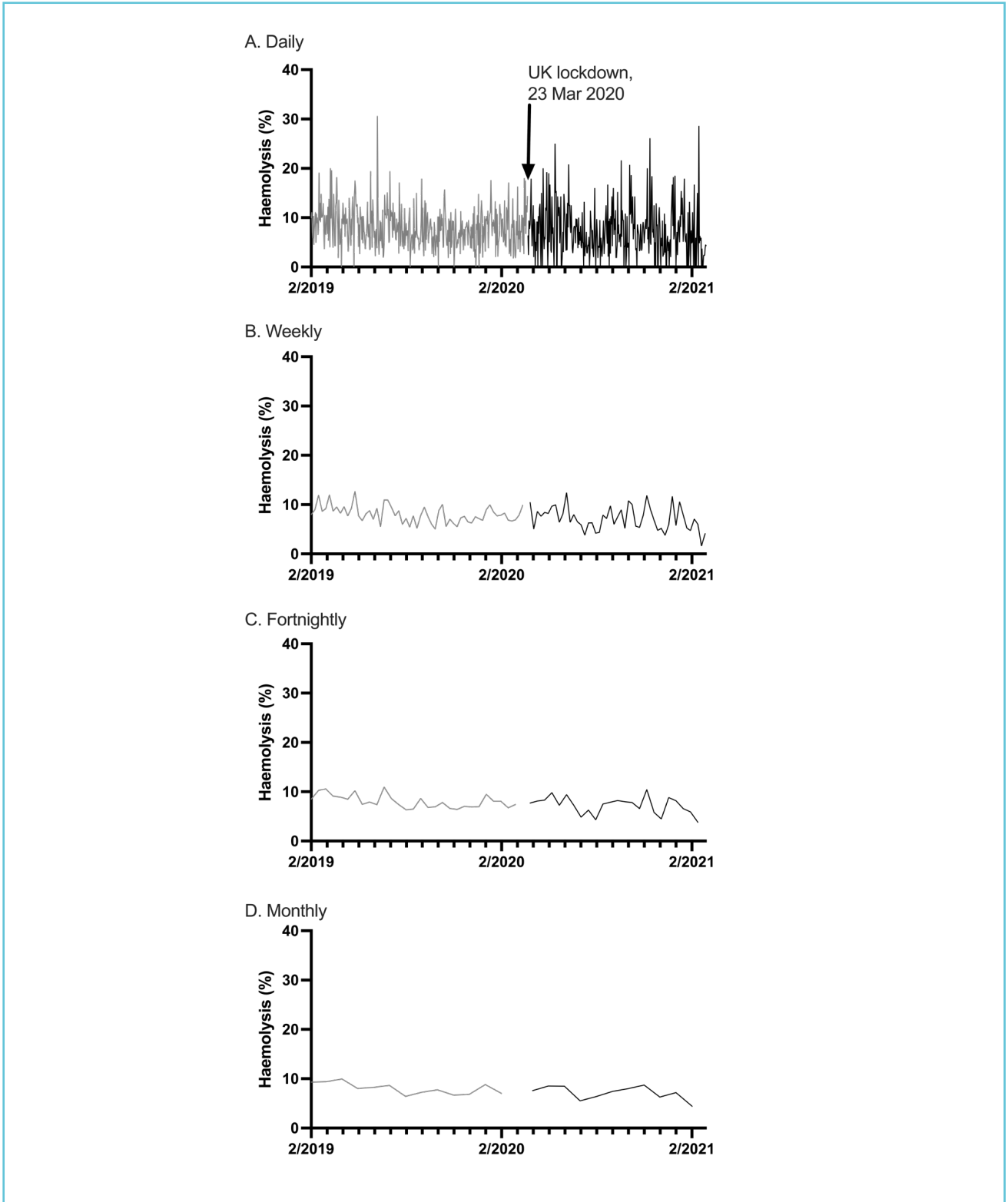
**Figure 2** Haemolysis cases (A) by number and (B) proportion, compared to the number of reports per day



**Figure 3** Daily haemolysis rates by day of the week, (A) pre- and (B) post- intervention, and (C) the proportion of occasions in which no haemodialysis cases occurred. (D) The same data as A and B, presented by day



**Figure 4** (A) Daily, (B) weekly, (C) fortnightly and (D) monthly haemolysis rates pre-intervention (grey line) vs. post-intervention (black line)





## HAEMOLYSIS RATES IN DIFFERENT WARDS

The front of house assessment units admit patients from the Emergency Departments, Clinics and General Practitioners for initial/confirmation of diagnosis and treatment. Below in Table 1 is a summary of daily pre and post COVID-19 haemolysed samples, total samples processed and haemolysis rates from the three front of house units (A. Clinical Decisions Unit; B. Acute Medical Unit and C. Acute Assessment Unit) in a local North-East England Trust.

Overall, results in the table 1 confirm a mean reduction in the number of sample processed

post in comparison to the pre COVID-19. The greatest reduction was observed in the Acute Assessment Unit (6.23 post versus 17.07 pre-COVID-19). However, there was a slight increase in the samples processed post compared to the pre COVID-19 period in the Acute Medical Unit (20.47 versus 19.51 respectively).

Results from the Acute Assessment Unit show a slight decrease in mean haemolysis rate post-COVID-19, 7.75 (pre) and 7.53 (post),  $p=0.812$ . The mean decrease in the mean score was 0.22% at 95% confidence interval. The unit admitted patients with suspected and confirmed COVID-19 infection.

**Table 1** Summary of daily pre and post COVID-19 haemolysed samples, reports, and haemolysis rates by ward. Three tables are presented under each unit: A. Clinical Decisions Unit; B. Acute Medical Unit; C. Acute Assessment Unit: the daily haemolysis cases (i), the total number of samples (ii) and the proportion (%) of haemolysed cases (i.e. i/ii) as (iii).

A. Clinical Decisions Unit		
i: Number of occurrences of haemolysis per day		
	mean (range)	<i>p</i> -value
Pre-	1.02 (0-5)	<0.0001
Post-	0.57 (0-4)	
Overall	0.81 (0-5)	
ii: The total number of samples analysed per day		
	mean (range)	<i>p</i> -value
Pre-	11.80 (2-25)	<0.0001
Post-	7.78 (1-17)	
Overall	9.98 (1-25)	

iii: Proportion of haemolysed samples, expressed as a percentage		
	mean (range)	p-value
Pre-	8.73 (0-57)	0.0570
Post-	7.30 (0-100)	
Overall	8.08 (0-100)	

### B. Acute Medical Unit

i: Number of occurrences of haemolysis per day		
	mean (range)	p-value
Pre-	1.57 (0-9)	0.2389
Post-	1.45 (0-9)	
Overall	1.51 (0-9)	

ii: The total number of samples analysed per day		
	mean (range)	p-value
Pre-	19.51 (6-44)	0.0512
Post-	20.47 (3-42)	
Overall	19.94 (3-44)	

iii: Proportion of haemolysed samples, expressed as a percentage		
	mean (range)	p-value
Pre-	7.88 (0-33)	0.0435
Post-	6.90 (0-30)	
Overall	7.44 (0-33)	

C. Acute Assessment Unit		
i: Number of occurrences of haemolysis per day		
	mean (range)	p-value
Pre-	1.32 (0-6)	0.0001
Post-	0.45 (0-5)	
Overall	0.93 (0-6)	
ii: The total number of samples analysed per day		
	mean (range)	p-value
Pre-	17.07 (4-30)	<0.0001
Post-	6.23 (0-23)	
Overall	12.17 (0-30)	
iii: Proportion of haemolysed samples, expressed as a percentage		
	mean (range)	p-value
Pre-	7.75 (0-36)	0.8120
Post-	7.53 (0-100)	
Overall	7.67 (0-100)	

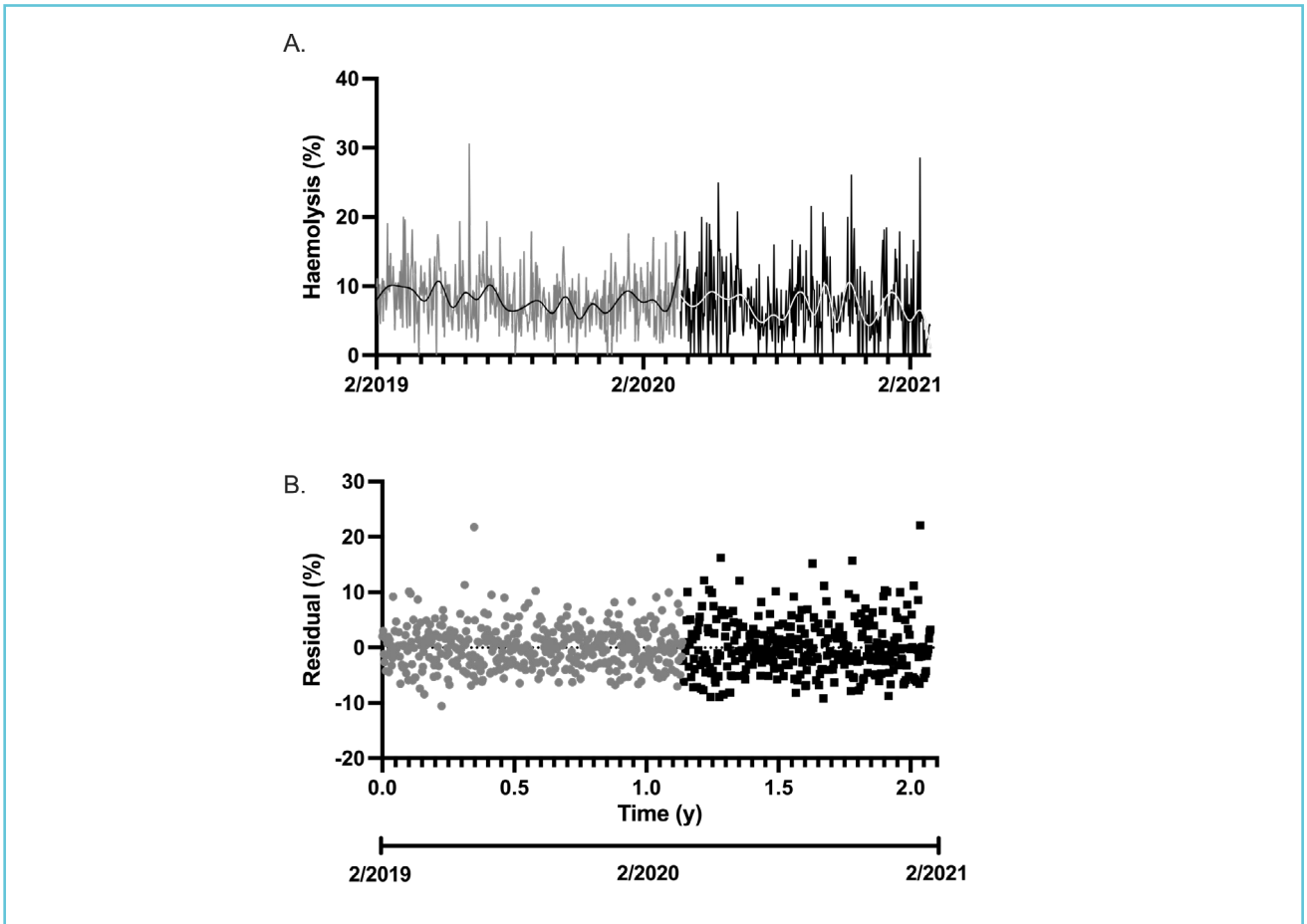
#### DETERMINING UNDERLYING TEMPORAL TRENDS IN HAEMOLYSIS RATE

Daily haemolysis rate was fitted with a model (spline curve) to visualise any underlying seasonality and long-term trends (Figure 5a). No clear periodicity, such as might be explained by seasonality, is evident. Figure 5b presents the residual variation in daily haemolysis after

‘removing’ (i.e. modelling) longer-term trends. Table 2 describes the data.

The comparison of residual haemolysis rate for the two periods of pre- and post-intervention (i.e. lockdown) allows a better understanding of variability in haemolysis. The median residual rate, which is always close to zero if seasonality and long-term trends are accurately modelled,

**Figure 5** (A) Daily haemolysis rates, pre-intervention (grey line) vs. post-intervention (black line). Superimposed is a spline curve for each of the two periods: pre- (black line) and post-intervention (white line). (B) Residual haemolysis rate



is less meaningful than the comparison of the variability.

To determine whether there were temporal trends in haemolysis rates, linear regression was performed pre- and post-intervention (Figure 6). From this analysis, the slope helps us to characterise how haemolysis rates change over time, i.e. long-term changes in rates. Likewise, comparing the intercept before and after the first lockdown (in order to compare pre-COVID-19 rates with rates observed during the pandemic) allows us to see if there has been an immediate effect, i.e. a short-term change in rate, because of changes in clinical practices because of the

pandemic. The pre-intervention slope was  $-1.70 \text{ \%} \cdot \text{y}^{-1}$  and its y intercept, 9.04%. The post-intervention slope was  $-1.88 \text{ \%} \cdot \text{y}^{-1}$  and its y intercept was 10.2%. There was no difference in either the slope ( $F$  test,  $p=0.87$ ) or intercept ( $F$  test,  $p=0.16$ ).

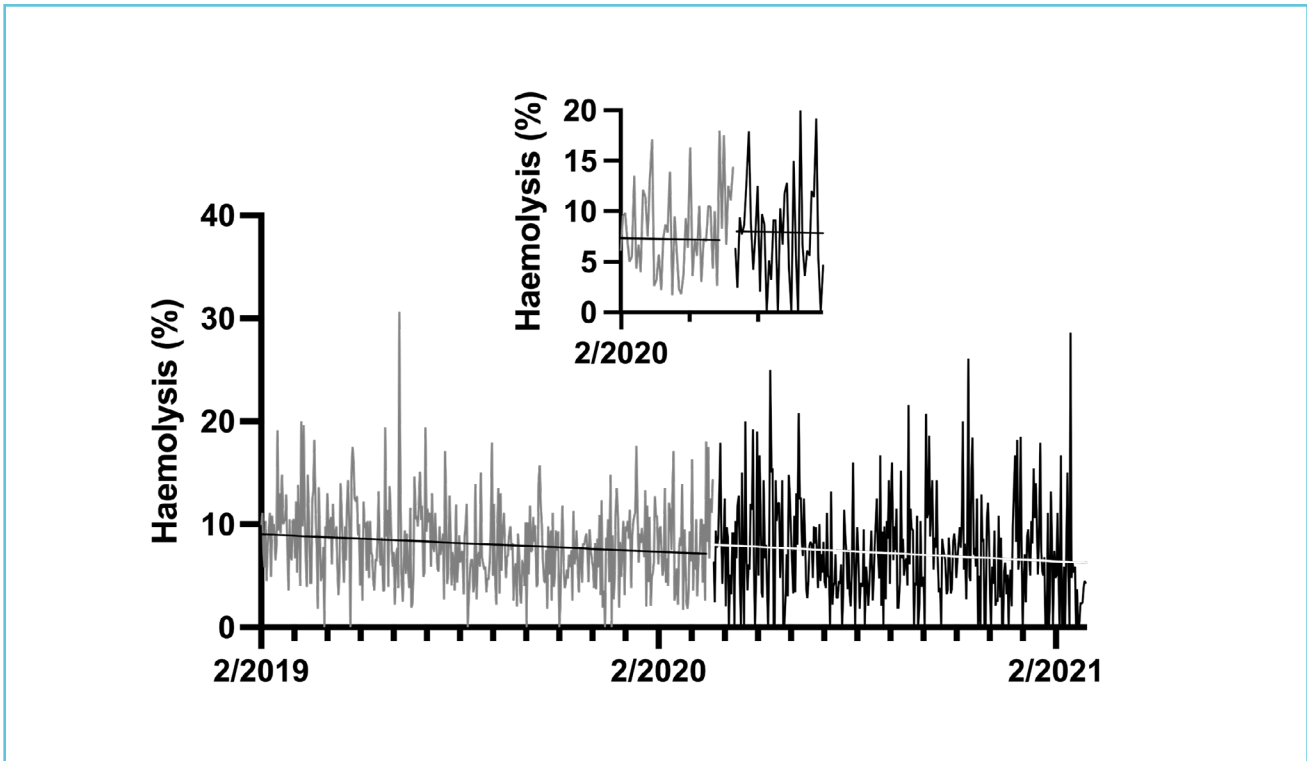
## DISCUSSION

This analysis sought to determine whether short-term variation in the outcome (i.e., any change in haemolysis rates) is explained by the exposure of interest (lockdown and changes in practice due to COVID-19 disease). There were

**Table 2** Residual haemolysis rate

	Pre-intervention	Post-intervention
No. values	416	343
Minimum (%)	-10.55	-9.190
25% percentile (%)	-2.747	-3.117
Median	-0.046	-0.601
75% percentile (%)	2.154	2.518
Maximum	21.76	22.08
Range	32.31	31.27

**Figure 6** (A) Daily haemolysis rates, pre-intervention (grey line) vs. post-intervention (black line). Superimposed is a linear regression for each of the two periods: pre- (black line) and post-intervention (white line). The inset shows a 6-week period either side of the intervention.



no significant differences in the long-term trend, with a haemolysis rate slowly falling over time that is unaffected by the UK lockdown and the pandemic (slope:  $-1.70\% \cdot y^{-1}$  prior to the 23 March 2020 lockdown vs.  $-1.88\% \cdot y^{-1}$  in the following year). Likewise, there was no short-term effect observed, with the intercept of haemolysis rate over time with no difference for these two periods. These results confirm the initial assumption in the trend of pre-analytical blood sample haemolysis rate; where temporary increase in the rate secondary to COVID-19 Disease, followed by a drop and revert to the pre-COVID levels, was predicted.

These findings contradict previously reported findings in literature (11; 12) where high haemolysis rates were presented in patients admitted with respiratory diagnoses. COVID-19 disease as a condition affecting the respiratory system does not seem to have an impact on pre-analytical blood sample haemolysis rate in this study. Seasonal and long-term patterns in both the exposure and the outcome can dominate crude association, making the short-term association of interest hard to detect (16). Such trends could be due to genuine physiological changes when dealing with biological data as well as external factors (17). The more residuals in the post intervention phase may have been associated with patient acuteness at the time of presentation to hospital. It may have also been related to external factors such as those pertaining to blood sample collection, associated venepuncture training and competence attainment. As the current data is based on population level, the distribution of common confounders is unlikely to change (16). Therefore, the observed results should be due to the impact of lockdown and changes in practice due to COVID-19 disease.

Overall, there was a reduction in pre-analytical blood sample haemolysis over the study period. Nonetheless, the acute medical unit had

a significant mean reduction in haemolysis rate post COVID-19 (7.88% versus 6.90%,  $p=0.0435$ ). The unit is 30 bedded and the largest of the 3 with equally large volume of samples collected by a cohort of in-house staff. The findings may be linked to the negative correlation between haemolysis rate and the number of samples processed. The repeated conduct of venepuncture may have contributed to increased competence and confidence amongst staff. These factors may also be secondary to the knowledge acquired during venepuncture training including competence attained.

Almost 83% of the respondents to a survey conducted in the same Trust as the current study reported to have achieved venepuncture competences (22). Furthermore, there was an overall increase in confidence at the last performed venepuncture reported across all staff categories (phlebotomist, nurses, health care assistants and doctors) involved in the conduct of venepuncture (22). However, such confidence may depend on the quality of venepuncture training and the support that learners receive within the clinical area. Venepuncture training provided during the study period in the Trust included face-to-face theory and practical and competence attainment completed within the clinical area. Clinical support in achieving competences contributed to pre-analytical blood sample haemolysis reduction (18; 19; 20). Moreover, there is usually a delayed effect of an intervention such as venepuncture training on pre-analytical blood sample haemolysis rate (21). The pattern in pre-analytical blood sample haemolysis rate over time may reflect the impact of venepuncture training being delivered in the Trust.

## **LIMITATION AND RECOMMENDATIONS**

Analysis of impact of COVID-19 disease on pre-analytical blood sample haemolysis has been done using data from one unit admitting patients

with suspected or confirmed COVID-19 infection. The data used did not contain information of the patients' presenting diagnosis. It is not known the extent to which lack of exact diagnosis may have had on the results. It is recommended that similar studies consider obtaining the patients' presenting and or confirmed diagnosis so a clear correlation data analysis between the presenting diagnosis of COVID-19 and haemolysis rate is conducted.

There were challenges brought about by the pandemic such as social distancing restrictions and low staff attendance to training including that of venepuncture. Likewise, there were less face-to-face sessions during this period than there usually are. The Clinical Decisions Unit, situated off the main Trust site was the most affected with almost all the sessions cancelled. It is not known the impact such restrictions may have had on the training internal validity and overall venepuncture practice, and on pre-analytical blood sample haemolysis. If there was any impact, it seems to have been low. However, future studies on the subject should consider the impact on the trend of the independent (e.g., venepuncture training) on dependent (e.g., pre-analytical blood sample haemolysis rate) variables when changes are implemented.

Similarly, changes introduced in some services in the hospital, such as outpatient departments, meant that staff were moved to the acute departments, such as the admissions units. Some of the staff may not have previously attended formal venepuncture training or refresher. Due to the demand posed by the pandemic, the staff may have been performing venepuncture. There is no evidence the involvement impacted in variability in the rates.

Furthermore, there was a difference of 73 data points between the pre and post-intervention phases in the dataset used in the current study. The pre-intervention phase had the most data

points, 416 compared to 343 post intervention. This may have had some influence in the current results; however, this is not known. It is recommended that similar future studies consider having equal data points for pre and post intervention to minimise bias caused by such variation.

## CLINICAL IMPLICATION

The study has highlighted lack of association of COVID-19 disease on pre-analytical blood sample haemolysis. Such understanding will facilitate the development of clinical pathways in the disease area. The inverse relationship between the venepuncture episodes and haemolysis rate underscores the importance of venepuncture proficiency on haemolysis rate reduction.

## CONCLUSION

The current study shows the lack of impact of COVID-19 disease as a respiratory condition, on pre-analytical blood sample haemolysis. The continued reduction in pre-analytical blood sample haemolysis rate confirms consistency venepuncture processes despite the risk transmission. Furthermore, the continued pre-analytical blood sample haemolysis rate reduction confirms positive impact of a general venepuncture training.



## Conflicts of interest

NM was a clinical educator in the local NHS Trust and had previously worked as a clinical nurse in the acute medical unit. JSY has undertaken contract research for Takeda and Boston Scientific; worked with Pfizer on an EU FP7 -funded research project, 'INCOMB'; performed consultancy for TENA, Performics, Zenith and PALL Europe; and received funding from Astellas

for the operational costs of running an annual conference.

### **Funding**

The research was part of academic work and had no sources of funding attached.

### **Acknowledgement**

I am grateful to Prof. Greg Atkinson and to Prof. Alan Batterham for their contribution at the start of this research.



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