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REPORTS OF ORIGINAL INVESTIGATIONS

Breath alcohol of anesthesiologists using alcohol hand gel and the "five moments for hand hygiene" in routine practice

Taux d'alcool dans l'air expiré des anesthésiologistes utilisant un gel pour les mains alcoolisé et les « cinq indications à l'hygiène des mains » dans la pratique courante

Helen A. Lindsay, MBChB · Jacqueline A. Hannam, PhD · Charles N. Bradfield, MBBCh · Simon J. Mitchell, PhD

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Abstract

Purpose *Appropriate hand hygiene reduces hospital-acquired infections. Anesthesiologists work in environments with numerous hand hygiene opportunities (HHOs). In a prospective observational study, we investigated the potential for an anesthesiologist to return a positive alcohol breath test during routine practice when using alcohol hand gel.*

Methods *We observed ten volunteer anesthesiologists over four hours while they implemented the World Health Organization (WHO) "five moments for hand hygiene" using our hospital's adopted standard 70% ethanol hand gel. We measured the expired alcohol concentration at shift start and every fifteen minutes thereafter with a fuel cell breathalyzer calibrated to measure the percentage of blood alcohol concentration (BAC). Blood alcohol specimens (analyzed with gas chromatography) were collected at shift start and, when possible, immediately after a participant's first positive breathalyzer test.*

Results *Of the 130 breathalyzer tests obtained, there were eight (6.2%) positive breath alcohol results from six of the ten participants, all within two minutes of a HHO. The highest value breathalyzer BAC recorded was 0.064%, with an overall mean (SD) of 0.023 (0.017)%. Five (62.5%) of the positive breathalyzer tests returned to zero in less than seven minutes. All of three blood specimens obtained immediately after a positive breathalyzer reading tested negative for alcohol.*

Conclusion *Anesthesia practitioners using alcohol hand gel in a manner that conforms with recommended hand hygiene can test positive for alcohol on a breathalyzer assay. Positive tests probably arose from inhalation of alcohol vapour into the respiratory dead space following gel application. If workplace breath testing for alcohol is implemented, it should be completed more than 15 min after applying alcohol hand gel. Positive results should be verified with a BAC test.*

Résumé

Objectif *Une hygiène des mains adaptée réduit les infections nosocomiales. Les anesthésiologistes travaillent dans des environnements leur donnant de nombreuses occasions de se laver les mains. Dans une étude observationnelle prospective, nous avons évalué le potentiel que l'éthylomètre d'un anesthésiologiste soit positif pendant la pratique courante lorsqu'il utilise un gel désinfectant alcoolisé pour les mains.*

Méthode *Nous avons observé dix anesthésiologistes volontaires sur une période de quatre heures pendant qu'ils appliquaient les « Cinq indications à l'hygiène des mains » de l'Organisation mondiale de la santé (OMS) en se servant de la norme adoptée dans notre institution, soit un gel pour les mains à base d'éthanol 70 %. Nous avons mesuré la concentration d'alcool expirée au début de leur quart de travail et toutes les quinze minutes par la suite à l'aide d'un éthylotest à pile à combustible calibré pour mesurer le pourcentage d'alcoolémie. Des spécimens de l'alcool sanguin (analysés par chromatographie en phase gazeuse) ont été recueillis au début du quart de travail et,*

H. A. Lindsay, MBChB (✉) · C. N. Bradfield, MBBCh · S. J. Mitchell, PhD
Department of Anaesthesia & Perioperative Medicine, Auckland City Hospital, 2 Park Road, Auckland, New Zealand
e-mail: helenl@adhb.govt.nz

J. A. Hannam, PhD · S. J. Mitchell, PhD
Department of Anaesthesiology, University of Auckland, Auckland, New Zealand

lorsque possible, immédiatement après le premier éthylotest positif d'un participant.

Résultats *Parmi les 130 éthylotests obtenus, 8 résultats (6,2 %) étaient positifs à l'éthylomètre, provenant de six des dix participants, tous obtenus dans les deux minutes suivant un geste d'hygiène des mains. Le taux d'alcoolémie le plus élevé enregistré était de 0,064 %, avec une moyenne globale (ÉT) de 0,023 (0,017) %. Cinq (62,5 %) des éthylotests positifs sont retombés à zéro en moins de sept minutes. Les trois spécimens sanguins obtenus immédiatement après un éthylotest positif étaient négatifs quand testés pour l'alcool.*

Conclusion *Les praticiens en anesthésie utilisant le gel alcoolisé pour les mains de manière conforme aux recommandations en matière d'hygiène des mains peuvent avoir un résultat positif à un alcotest. Les tests positifs ont probablement été provoqués par l'inhalation de la vapeur d'alcool dans l'espace mort respiratoire après l'application du gel. Si on met en place un alcotest au travail, ce test devrait être réalisé plus de 15 min après avoir appliqué un gel pour les mains à base d'alcool. Les résultats positifs devraient être vérifiés à l'aide d'un test de taux d'alcoolémie dans le sang.*

Hospital-acquired infection and multidrug-resistant pathogens are a source of major health and financial cost in modern healthcare systems.[1] The potential contribution of the anesthetic work environment to infection transmission is being increasingly recognized. Hand hygiene is proven to be the single most cost-effective measure in preventing hospital-acquired infection, with the World Health Organization (WHO) "five moments for hand hygiene" model defining the current gold standard for optimal hand hygiene behaviour.[2-5] The feasibility of applying this standard when administering an anesthetic has been challenged.[6-8] Compliance is frequently poor in anesthetic environments, even if convenient alcohol hand gel preparations are used.[6-10] Nevertheless, it is the policy of hospital administrators and the Health Quality & Safety Commission New Zealand that all healthcare workers comply with the five moments approach.[5]

Systemic alcohol absorption is a potential unintended consequence of the high number of hand gel applications required to comply with the five moments when giving an anesthetic.[11,12] Even very low levels of absorption are potentially important because sensitive breathalyzer devices are sometimes used for workplace screening of medical professionals returning to work after rehabilitation from drug or alcohol addiction. In this context, there is usually a zero reading requirement to pass the test, and the implications of a positive test are serious. Although infrequently required, the management of such cases is a recognized issue among anesthesiologists who have a threefold higher rate of substance abuse compared with other physician groups.[13]

We aimed to establish whether the practice of optimal hand hygiene with alcohol hand sanitization, as prescribed by the WHO "five moments for hand hygiene", could result in positive breathalyzer assays for alcohol during routine anesthetic practice. Blood alcohol concentration (BAC) measures followed the positive breathalyzer assays to determine if the breathalyzer results were spurious.

Methods

The University of Auckland Human Participants Ethics Committee (reference 015088) and Auckland District Health Board Research Office (A+ 6771) approved this prospective observational study (July 2015). Ten anesthesiologists from the Adult Anaesthetic & Perioperative Department at Auckland City Hospital were recruited from August-November 2015. All participants gave written informed consent prior to being enrolled in the study. Exclusion criteria included alcohol consumption within 24hr of observation, allergy to the hand gel preparation, any current hand rash, and pregnancy or lactation. Participants were allocated a study number, and all data were linked to this study number for anonymity. The operating room (OR) teams were orientated to the purpose of breathalyzing the participating anesthesiologists.

Participants were observed during a four-hour period (i.e., a single morning half-day shift) in an OR where they worked as an independent anesthetic practitioner on a routine operating list. They were instructed to implement the WHO "five moments for hand hygiene"[5] using the hospital standard 70% alcohol hand gel (Microshield Angel Blue antimicrobial hand gel, 70% v/v absolute ethanol, Johnson & Johnson, Australia). At each identified "moment" (hereafter referred to as a hand hygiene opportunity [HHO]), a hand wash was performed. This involved applying 2 mL (i.e., one squirt) of alcohol gel and rubbing the gel over the bare skin of both hands and wrists until dry. To ensure compliance with WHO and hospital hand hygiene policy and to establish consistency between participants, the investigator (H.A.L.) prompted the participant in the case of a missed HHO. The timing of each initiated and prompted HHO was recorded, where time zero marked the first application of alcohol hand gel. Key anesthetic events were recorded, including the patient entering or leaving the OR, induction, and airway manipulation. Adverse events from the participants'

exposure to the alcohol hand gel were also recorded. Prior to observation, all participants completed a background questionnaire comprising relevant demographic detail (age, ethnicity, sex, body mass index) and average weekly alcohol consumption (where one standard unit contains 14 g of alcohol).[14]

Breathalyzer testing

An Alcosense® Precision+ Fuel Cell Breathalyzer (Andatech Corporation Pty Ltd, Vermont Australia) was used in accordance with manufacturer instructions for the breathalyzer assessments. This device was calibrated to Australian standard AS 3547 to meet the workplace testing specifications applicable in New Zealand. Specifically, the breathalyzer was calibrated to report results in the standard unit of % BAC, with a sensitivity threshold of 0.000% - 0.001% BAC and accuracy ± 0.005% BAC at 0.100% BAC. A reading of 0.001% BAC or 1 mg of alcohol per decilitre of blood is approximately equivalent to 5 μg of alcohol per litre of breath. The legal BAC limit for driving in New Zealand is 0.05%.

A breath test was completed at baseline prior to the use of any alcohol hand gel. During the observation period, breathalyzer testing was completed at fifteen-minute intervals (as the clinical workload allowed). After any positive breath test, breathalyzer testing was increased to five-minute intervals (adhered to as closely as clinical activity allowed) until the level reverted to zero. The precise timing of each measurement was recorded. The investigator held the breathalyzer during all measurements to prevent detection of residual alcohol from the participant's hands.

Direct blood alcohol testing

A venous sample for BAC was taken at the beginning of the shift prior to the application of any hand gel and, if possible, immediately after the first positive breathalyzer reading. To collect blood samples, the participant's skin was cleaned with a non-alcohol-based iodine product, and the investigator washed her hands with an iodine surgical scrub before donning gloves. LabPLUS Auckland, the tertiary referral medical laboratory of Auckland City Hospital, measured the blood alcohol levels using gas chromatography with a sensitivity threshold of 5 $mg{\cdot}dL^{-1}$ (0.005%BAC).

Outcomes and statistical analysis

The primary outcome of the study was the proportion of anesthesiologists returning a positive breathalyzer test (> 0.001% BAC) based on at least one measurement collected during optimal hand hygiene practice with 70% ethanol hand gel during a routine half-day operating session. A sample size of ten participants was chosen by convenience as a feasible number to gain an appreciation of the prevalence and pattern of positive breathalyzer detection throughout a typical list. In the event of no positive detections in all ten cases, we recognized that interpretation would be limited due to the small number of cases.

Outcomes of secondary interest included the timing of any positive breathalyzer tests in relation to HHO exposure, BAC results from blood specimens taken immediately after a positive breathalyzer reading *vs* the breathalyzer BAC results, the total number and pattern of HHOs, and the proportion of HHOs prompted by the observer.

Outcomes were reported as absolute values, simple proportions, and means with standard deviation (SD) as appropriate.

Results

Five male and five female adult anesthesiologists participated in the study (see Table 1). Two of the females were senior trainees, while all other participants were specialist consultants. The participants' mean (SD) age and body mass index were 52 (10) yr and 26.4 (2.1) $kg{\cdot}m^{-2}$, respectively, for males and 40 (11) yr and 24.2 (4.1) $kg{\cdot}m^{-2}$, respectively, for females. All participants were of European ethnicity. Typical alcohol consumption ranged from less than 1-14 units per week for males and 1-7 units per week for females.

The baseline breathalyzer and blood samples for all participants were negative for alcohol. Subsequently, six of ten (60%) participants returned a positive breathalyzer (> 0.001% BAC) at least once during their half-day shift. Two participants produced a second positive test in the same shift. Thus, there were eight (6.2%) positive results from the 130 breathalyzer measurements taken over the entire study. The mean (SD) positive breathalyzer result was 0.023 (0.017)% BAC. One participant exceeded the legal limit for driving in New Zealand with 0.064% BAC on breathalyzer testing. All participants were observed for the full observation period (four hours), and none of the final breathalyzer tests were positive for alcohol.

All positive breathalyzer results were obtained within one to two minutes of applying hand gel. Additionally, the positive breathalyzer results quickly returned to zero. In seven of the eight positive tests, the breath test was negative by the time of the first repeat breathalyzer test. The timing of the first repeat test varied due to demands of patient management, and therefore, we were unable to maintain strict compliance with our plan to adopt a five-

Table 1 Demographics and results of hand gel use by participant, HHO adherence, and blood alcohol concentrations as recorded by breathalyzer and blood assay

Participant	Age, ethnicity, sex, BMI, weight and average weekly alcohol consumption	Gel Exposure and Number of Cases	% of HHOs Prompted	All Positive BREATH Alcohol Results (% BAC, after how many HHOs, and time since last HHO)	Corresponding BLOOD Alcohol Results (% BAC)
1	57 yr European Male, 26 $kg \cdot m^{-2}$ (90 kg)	67 HHOs	19%	0.013% after 21 HHOs, < 1 min	No sample[a]
	Averages 10 units alcohol/week	over 2 cases	(13/67)	0.015% after 26 HHOs, < 1 min	None detected
2	41 yr European Female, 24 $kg \cdot m^{-2}$ (66 kg)	89 HHOs	2%	0.012% after 75 HHOs, < 1 min	None detected
	Averages 1-3 units alcohol/week	over 5 cases	(2/89)		
3	41 yr European Male, 28 $kg \cdot m^{-2}$ (83 kg)	48 HHOs	33%	0.027% after 11 HHOs, < 2 min	No sample[a]
	Averages 14 units alcohol/week	over 2 cases	(17/48)	0.016% after 19 HHOs, < 2 min	No sample[a]
4	58 yr European Female, 18 $kg \cdot m^{-2}$ (48 kg)	30 HHOs	16%	Nil positive	
	Averages 3 units alcohol/week	over 2 cases	(5/30)		
5	42 yr European Male, 24 $kg \cdot m^{-2}$ (79 kg)	84 HHOs	Not measured	0.013% after 13 HHOs, < 1 min	No sample[a]
	Averages 13 units alcohol/week	over 2 cases			
	Disulfiram effect with red wine				
6	58 yr European Male, 29 $kg \cdot m^{-2}$ (100 kg)	16 HHOs	88%	Nil positive	
	Averages <1 unit alcohol/week	over 1 case	(14/16)		
7	33 yr European Female, 28 $kg \cdot m^{-2}$ (84 kg)	46 HHOs	13%	0.064% after 41 HHOs, < 1 min	None detected
	Averages 1-5 units alcohol/week	over 1 case	(6/46)		
8	30 yr European Female, 23 $kg \cdot m^{-2}$ (70 kg)	56 HHOs	7%	Nil positive	
	Averages 7 units alcohol/week	over 2 cases	(4/56)		
9	40 yr European Female, 28 $kg \cdot m^{-2}$ (84 kg)	46 HHOs	24%	Nil positive	
	Averages 1.5 units alcohol/week	over 2 cases	(11/46)		
10	62 yr European Male, 25 $kg \cdot m^{-2}$ (78 kg)	38 HHOs	58%	0.020% after 22 HHOs, < 1 min	No sample[a]
	Averages 7 units alcohol/week	over 3 cases	(22/38)		

[a] A blood sample could not be collected after the positive breathalyzer result due to the intensity of the clinical workload

BMI = body mass index; HHOs = hand hygiene opportunities; %BAC = % blood alcohol concentration. One standard unit of alcohol = 14 g of alcohol.[14]

minute interval testing regimen after positive tests. The first repeat was within seven minutes in five of the eight cases and within 15 min in seven of the eight cases. One participant had two sequential positive breathalyzer results at 15-min intervals. Unfortunately, demanding clinical activity precluded more frequent breath or blood testing in this individual. Clinical demands also meant that we were able to obtain only correlative blood samples immediately after three of the positive breathalyzer results, which included the one test that exceeded the limit for driving. All of these were negative for alcohol.

The exposure to alcohol gel varied from 16-89 HHOs across the ten participants, with a mean (SD) of 52 (23) HHOs in a four-hour period. This represented a mean (SD) of 26 (12) HHOs per case. The frequency of HHOs was consistently greater around the times of induction and extubation. The proportion of HHOs that required prompting from the investigator to ensure compliance with the "five moments" varied between participants and ranged from 2-87% of HHOs.

Participants' adverse experiences related to high-intensity use of alcohol hand gel were reported at the time of observation and in a follow-up survey of participants. All study participants remarked about the unpleasant nature of the residual hand gel after multiple exposures, and many also commented on the unpleasant alcohol aroma. Two female participants developed cold hands, with one sensing that it impaired her manual dexterity. Two participants observed skin peeling and dryness in the days following observation.

Discussion

We have shown that an anesthesiologist with zero blood alcohol at the start of a shift can test positive on a

breathalyzer alcohol test when using alcohol hand gel in compliance with the WHO "five moments for hand hygiene" during routine work in an OR. Indeed, 60% of our participants returned at least one positive test, and in one case, the value exceeded the legal BAC for driving in New Zealand (0.05% BAC). None of the positive breathalyzer tests recorded positive direct BAC measurements. An obvious question pertains to the mechanism of these falsely positive tests. Clearly, the anesthesiologists exhaled alcohol into the breathalyzer, but how did this occur?

Several studies have detected alcohol in blood samples after experimental exposures to alcohol hand gel.[11,12] These investigations prove that systemic absorption of alcohol can occur during use of topical gel preparations. Nevertheless, the blood levels recorded in these studies were invariably very low. Even in the study with the most aggressive exposure (20 × 4 mL applications of 95% ethanol gel spaced evenly over 30 min), the median peak blood level was only 0.002% BAC, and this slowly declined to 0.001% BAC over one hour.[11] In contrast, the positive breathalyzer readings in our study were considerably higher (0.016-0.064% BAC), yet remarkably evanescent -that is, they invariably became negative by the time the first repeat breathalyzer measurement was taken (within 2-15 min after the positive test). Moreover, the blood tests from the three participants whose samples were obtained immediately after a positive breathalyzer reading were all negative for alcohol -this despite the breathalyzer result implying a BAC well above the lower threshold of sensitivity for the blood alcohol assay.

Two relevant studies have been conducted in real-world clinical environments.[15,16] Both involved healthcare workers using alcohol hand gel in a hospital ward, and in both studies, the workers underwent breathalyzer and blood testing for alcohol at the end of a four-hour shift within two minutes of their final application of 70% ethanol hand gel. In the first study, where the average worker used hand gel nine times over their shift, 28 of 86 (32.5%) participants returned a positive breathalyzer test [mean (SD) 0.015 (0.01)% BAC].[15] In the second study, where the average worker used hand gel 11 times over their shift, ten of 26 (38.5%) participants returned a positive breathalyzer test [mean (SD) 0.016 (0.014)% BAC].[16] Only one of the participants across both studies tested positive for alcohol on a blood specimen taken at the same time as the positive breathalyzer test (see further comment on that case below). Moreover, although the study did not describe the protocol for breathalyzer monitoring after these positive tests, reported results indicated that all participants returned a negative test "within 15 min".

These two clinical studies differed from our own; for instance, we recruited only anesthesiologists, applied a recommended institutional standard to define hand hygiene opportunities, and conducted serial breathalyzer tests every 15 min *vs* solely at the end of the shift. Nevertheless, there were important similarities in the results of all three studies that help inform us of the mechanism for positive tests. First, all positive breathalyzer BAC results were substantially higher than the alcohol levels measured from blood samples in the simulation investigations[11,12] that demonstrated the feasibility of systemic absorption of alcohol during use of hand gel. Second, despite these relatively high levels, all three studies reported that repeat breathalyzer testing became negative within minutes of a positive result. In view of the slow decay in systemic blood levels described by Kramer *et al.*,[11] this result would be unexpected if systemic absorption were truly the explanation for the positive tests. Third, only one of 44 participants returning a positive breathalyzer result across the three studies was found to have alcohol detectable in blood samples drawn at the same time as the positive test. Also, that result (0.000022% BAC) was so low as to be consistent with normal physiological levels of ethanol.[15] Finally, all positive tests in all three studies were recorded in temporal relation (within a few minutes) to the application of alcohol hand gel.

Collectively, these observations suggest that something other than systemic absorption is likely responsible for positive breathalyzer tests in clinicians using alcohol hand gel. In our view, the most plausible explanation is re-expiration of inspired alcohol vapour that remains in the respiratory dead space. The authors of the other two clinical studies described above also reached this conclusion.[15,16] In a formal extension to their work, they detected significant levels of ethanol vapour in the air around the entrance to the airway during use of alcohol hand gel.[17] We also informally explored the hypothesis of breath contamination by simulating various gel application scenarios. We found that an individual could produce a positive breathalyzer result after just one gel application (data not shown) by rubbing their hands with gel close to their airway or by incidentally rubbing their face with gel on their hands. On one occasion, in the absence of alcohol consumption or gel application for more than 24 hr, an inhalation near freshly applied alcohol hand gel produced a breathalyzer result of 0.227% BAC (almost five times the legal limit for driving in New Zealand). In this setting, it is completely implausible that systemic absorption could account for the positive reading. One participant in our study had two sequential positive breathalyzer results at 15-min intervals, but demanding clinical activity precluded more frequent breath or blood testing. Importantly, there were other HHOs within one to two minutes prior to the second positive test and, considered in the context of the above discussion, it seems most likely that this case

represented two consecutive examples of breath contamination and not an example of systemic absorption.

Our findings have implications for routine breathalyzer testing of previously impaired anesthesiologists making a supervised return to the clinical environment. In this setting, a zero tolerance policy to blood alcohol levels is routinely imposed and the implications of a positive test are serious. Our study shows that, in routine clinical practice, an anesthesiologist could return a spurious positive breath alcohol test through compliance with recommended use of alcohol hand gel. We therefore recommend that, in an OR where alcohol hand gel is being used, breathalyzer testing should not be conducted within 15 min of hand gel application and that the tester, not the subject, should hold the test apparatus. We also recommend that any positive breathalyzer test should be repeated after five minutes of carefully monitored abstinence from use of hand gel. A negative test under these circumstances would indicate that alcohol is not present in the blood and that the initial positive result was most likely due to alcohol vapour contaminating the expired breath. It may also be wise to submit a contemporaneously collected blood sample for assay, but it must be understood that some assays are sufficiently sensitive to detect physiological levels of alcohol.

Our study has several limitations. First, we were unable to obtain a blood sample and sufficiently frequent repeat breathalyzer tests in all participants who returned positive breathalyzer results. This occurred because the anesthesiologists were unable to pause for blood specimen collection or repeat breathalyzer tests due to patient management priorities. Second, although an investigator who was thoroughly familiar with the "five moments" prescription undertook to observe and prompt the HHOs, it is possible that not all HHOs were observed or recorded correctly. Similarly, some subjects expressed concern about complying with the "five moments" during time-critical events such as intubation. This resulted in missing a small number of HHOs. Nevertheless, the number of HHOs completed in this study is consistent with data reported for anesthesiologists in other studies.[6-8] Third, most participants remarked that, by following the "five moments" prescription, they used alcohol hand gel more frequently than they typically would in their usual practice. It follows that positive breathalyzer tests may be less likely than our data suggest when anesthesiologists invoke their usual hand hygiene habits. We considered it desirable to adjust the exposure of participants to a reasonably repeatable standard. Moreover, since there are campaigns to encourage all healthcare professionals to adhere to the "five moments",[5] we considered that this standard had demonstrable clinical relevance. Finally, we acknowledge that our interpretation of the mechanism of the positive tests is based on an evaluation of circumstantial evidence rather than on the outcome of experiments specifically designed to isolate the mechanism of positive tests. Irrespective of these limitations, the key finding that spurious positive tests are possible in this setting remains valid.

As a secondary issue, our study highlighted the feasibility of concerns about the "five moments" approach in anesthesia. Without prompting, many participants would have missed numerous HHOs. While some participants improved compliance after initial prompting, others responded by adjusting their practice to avoid HHOs. While the latter was an unintended consequence, it served to highlight an important issue for the investigators. In making effective hand hygiene a feasible goal for anesthesiologists, the focus of future research should be on how to improve work processes and environments to limit the number of HHOs required rather than on measuring compliance. The unpleasant drying and cooling effects on skin that can be associated with high-intensity use of alcohol hand gel is also important when considering the feasibility of compliance with the "five moments" in the anesthetic environment.

In conclusion, an anesthesiologist's recent use of alcohol hand gel in the OR can return a positive breath alcohol test. This is most likely caused by inhaled alcohol vapour contaminating the dead space gas following application of hand gel, and the positive test is cleared within minutes. We recommend that workplace breath testing be completed more than fifteen minutes after any application of alcohol hand gel. The person administering the test should hold the breathalyzer and not use alcohol hand gel. We also recommend to repeat any positive breathalyzer test after five minutes, with due care to avoid any possible contamination by alcohol vapour, and to correlate the repeat test with a blood alcohol assay of a contemporaneously collected sample.

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