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ESTIMATING CARBON DIOXIDE CONCENTRATION NEAR AN INFANT'S FACE, CASE 95-43604.

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DEPARTMENT OF NATIONAL DEFENCE - CANADA

Executive Summary

Dr. Stephen Wetmore, Coroner, Ministry of the Solicitor General, asked DCIEM to investigate the possibility that carbon dioxide build-up may have been a predisposing factor in the death of an infant. This is an account of the circumstances surrounding the death, the methods used to examine the hypothesis, the results and a discussion with recommendations regarding the results.

The 4-month old infant had just been released from the hospital after a serious respiratory infection. It was transported home in an infant carrier in the back seat of the car. The carrier was covered with a quilted blanket to protect the baby from the sun. Upon arrival at home the infant was not breathing and after some brief resuscitative efforts was rushed to hospital where he was resuscitated in the emergency department. The baby died three days later with the post-mortem indicating pneumonia and tracheal infection.

CO_2 rebreathing has been considered as a causal factor in some infant deaths. The rebreathing is usually associated with the position of the baby's face in relation to bedding, the material and thickness of the bedding and the convective air flow conditions near the baby's face.

Dr. Wetmore provided the infant carrier, the blanket and the baby's clothing. DCIEM developed experimental methods to estimate the baby's possible exposure to carbon dioxide. The potential for carbon dioxide build-up of the bunting bag and blanket combination was also established using a technique developed by Kemp and Thach[1] that quantifies the potential of specific conditions for rebreathing.

The experimental methods showed that carbon dioxide build-up in the range of 1 to 2% was possible near the mouth of an infant in a covered carrier. Environmental conditions in the car at the time were unknown so that a confident estimate could not be made of the difference between the laboratory and actual conditions.

The carbon dioxide levels were within the acceptable range for healthy adults; they may not have been for a child who had recently experienced respiratory infection. In any case, the recommendations and findings of other researchers should be re-iterated, i.e., ensure that there is good ventilation in the room and keep thick bedding and tight fitting clothing away the child's face.

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of the first 30 mL stroke exhaust stroke of the syringe (1). The half-time, t = t1/2, was the time required for the concentration to drop to 1/2 the initial value (2) along a line interpolated between the peaks. 15

September 3, 1997

Estimating Carbon Dioxide Concentration Near an Infant's Face, Case 95-43604.

David Eaton

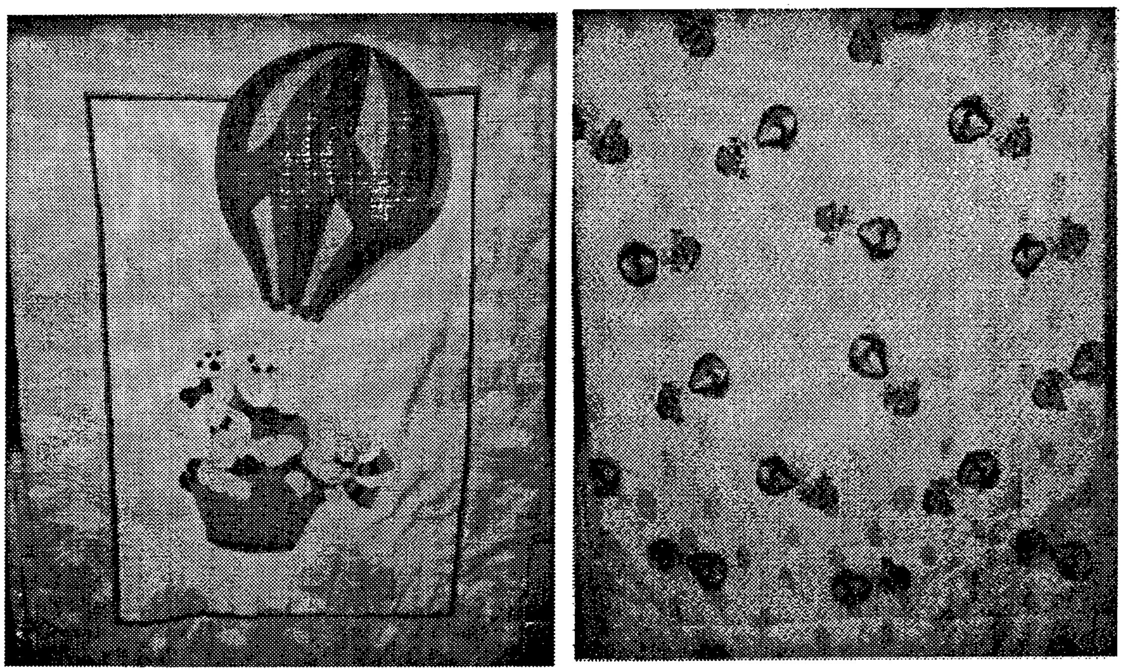
Investigation of the hypothesis that carbon dioxide rebreathing was a factor in the case of infant death 95-43604 for London, Ontario Regional Coroner's Office.

Dr. Stephen Wetmore, Coroner, Ministry of the Solicitor General, asked DCIEM to investigate the possibility that carbon dioxide build-up may have been a predisposing factor in the death of an infant. The following is an account of the circumstances surrounding the death, the methods used to examine the hypothesis, the results and a discussion with recommendations regarding the results.

1.0 BACKGROUND

A 4-month old, male infant, who had been born pre-maturely, spent two months in hospital before being released in the care of his parents. The infant had an abnormal right lung (hypoplastic and partly bound down) and dextro-version right-sided deviation of the heart. He subsequently, developed a respiratory infection and was admitted to the hospital in March and treated for over one month. On the day of discharge from the hospital at the beginning of May, the mother and grandmother dressed the baby and put him in a bunting bag which they zipped up to the chin and put the hood up. The baby was placed in an infant carrier and put in the back seat of the car. To shade the baby from sunshine, a quilted blanket, Figure 1, was placed over the infant carrier such that the baby was completely covered. Apart from some brief noises the baby was quiet during the ride home. When they arrived home, after 45 minutes in the car, mother and grandmother checked the baby and found that the bunting bag had slipped up over the mouth of the infant. The infant was not breathing and after some brief resuscitative efforts was rushed to hospital where he was resuscitated in the emergency department. The baby died three days later with the post-mortem indicating pneumonia and tracheal infection. The baby's mass was 3390 g.

Dr. Wetmore proposed that a build-up of carbon dioxide (CO_2) could have occurred while the baby was in the infant carrier under the blanket. The build-up may have exacerbated the infant's already weak respiratory health. CO_2 rebreathing has been considered as a causal factor in some infant deaths.[1,2,3,4,6] The rebreathing is usually associated with the position of the baby's face in relation to bedding, the material and thickness of the bedding and the convective air flow conditions near the baby's face. Kemp and Thach[1] developed a technique that quantifies the potential of specific conditions for rebreathing.



(a) (b)

FIGURE 1. Blanket used to cover infant in infant carrier; (a) shows poster side of blanket with the "hot air balloon" used as a reference; (b) shows wallpaper side of blanket.

Dr. Wetmore provided the infant carrier, the blanket and the baby's clothing. DCIEM developed experimental methods to estimate the baby's possible exposure to carbon dioxide. The potential for carbon dioxide build-up of the bunting bag and blanket combination was also established.

2.0 METHODS

Two types of investigations were conducted. The first examined different variables that could influence carbon dioxide build up and the second used the Kemp and Thach[1] technique to quantify the potential for carbon dioxide build-up.

2.1 Variables Influencing CO_2 build-up.

2.1.1 Apparatus.

A mannequin used in crash testing (First Technology Safety Systems, Plymouth, Michigan, New Born, 7.5 pound (3.4 kg)) was used to simulate the volume occupied by the infant in the infant carrier. The mannequin was placed in the infant carrier. A system of tubes were attached to the mannequin, Figure 2. One tube continuously drew 100 mL•min^{-1} of gas from the sample point (nose or mouth) and was connected to an infra red CO_2 analyzer (Analytical Development Co. Ltd., Model PM3A). Gas leaving the analyzer was brought back to the mannequin where it exhausted into the air adjacent to the sample point. Connected into the return line was a 100 mL glass syringe (Becton-Dickinson & Co.) which could be used to superimpose breathing patterns on the sample gas flow. The syringe allowed for control of the stroke volume and frequency of breathing patterns as well as a simulation of dead volume in the infant respiratory system. Additionally, a carbon dioxide injection line was connected into the return line from the analyzer. Carbon dioxide injection rate was regulated via an electronic flow controller (Brooks Instruments, Model 5851). The mannequin was placed in the bunting bag which was then zipped up and the collar raised to cover the mouth.

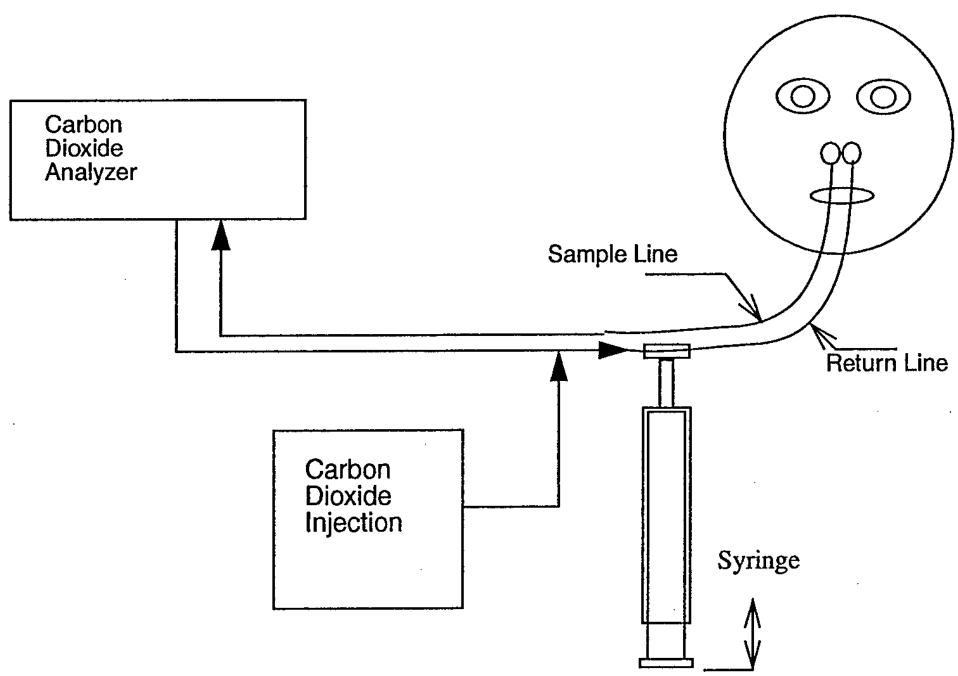


FIGURE 2. Apparatus for establishing effect of breathing variables on carbon dioxide build-up.

2.1.2 Design.

A number of variables were immediately identified as major influences on CO_2 concentration near the baby's mouth and nose. The variables and the levels considered are listed in Table 1.

TABLE 1. Variables considered during investigation of carbon dioxide concentration.

Variable	Levels
Blanket Status	no blanket
	blanket
Blanket Orientation	Poster Up, Balloon at Head
	Poster Up, Balloon at Feet
	Poster Down, Balloon at Head
	Poster Down, Balloon at Feet
Sample Point	Nose (outside clothing)
	Mouth (inside clothing)
Breathing	dead volume (0, 35, 70 mL)
	stroke volume (0, 15, 30, 15 mL)
	stroke frequency (0, 10, 15, 30 min^{-1})
CO_2 Injection Rate	0 to 45 $mL \cdot min^{-1}$

The experiment was divided into 7 parts, Table 2. In each part only one variable was changed. This produced 16 conditions. Part 1 served as a control to determine the background CO_2 concentration. Part 2 established the CO_2 concentration at three levels of CO_2 injection without breathing flow rates. Part 3 identified the influence of the blanket and the effect of its orientation. Part 4 examined the difference between the mouth and nose sampling points. Part 5 established the influence of stroke frequency. In this case the stroke volume was held constant so that increasing frequency increased the total ventilation. Therefore, to maintain the same injection concentration, the CO_2 injection rate was adjusted to maintain 4%. In Part 6 the effect of varying dead volume was examined. Part 7 examined the influence of stroke volume, but in this case the total ventilation rate was maintained at 450 $ml \bullet min^{-1}$ by varying stroke frequency.

CO_2 injection rates, stroke frequencies, stroke volume and dead volume were chosen based on a literature review. There were large variations in reported values for the different parameters; consequently, a base condition was chosen and other variables were selected to produce independent variation from that condition. The base condition included a dead volume of 70 mL, stroke volume of 30 mL and a stroke frequency of 15 min^{-1}. These three variables were set to match the values used in the method of Kemp and Thach[1] who selected them to fit a model of a 4-5 kg infant. This produced a minute ventilation of 450 $mL \bullet min^{-1}$. For this ventilation rate, a CO_2 injection concentration of 4% was considered reasonable based on the literature review; consequently, the base CO_2 injection rate was set at 0.04 x 450 = 18 mL.

TABLE 2. Conditions used to investigate the influence of environmental and human variables on carbon dioxide build-up.

Part		Blanket Status	Blanket Orientation	Sample Point	Dead Volume (mL)	Stroke Volume (mL)	Stroke Frequency (min^{-1})	CO_2 Injection Rate ($mL \cdot min^{-1}$)
1. Control		None	not applicable (NA)	Nose	NA	NA	NA	0
2. CO_2 Injection	a.	None	NA	Nose	NA	NA	NA	9
	b.							18
	c.							45
3. Blanket Orientation	a.	On	Poster up, Balloon at head;	Nose	NA	NA	NA	18
	b.		Poster up, Balloon at feet;					
	c.		Poster down, Balloon at head;					
	d.		Poster down; Balloon at feet.					
4. Sample Point		On	Worst Case of Part 3.	Mouth	NA	NA	NA	18
5. Stroke Frequency	a.	On	Worst Case of Part 3.	Worst Case of Parts 3 & 4.	70	30	10	12
	b.						15	18
	c.						30	36
6. Dead Volume	a.	On	Worst Case of Part 3.	Worst Case of Part 3 & 4.	0	30	15	18
	b.				35			
7. Stroke Volume	a.	On	Worst Case of Part 3.	Worst Case of Part 3 & 4.	70	15	30	18
	b.					45	10	

2.1.3 Procedure.

All tests in Part 1 through 7 lasted 10 minutes and were repeated 3 times. In Parts 1, gas was drawn through the sample tube by the carbon dioxide analyzer and returned to the mannequin for exhaust next to the sample point. In Part 2, gas was sampled and analyzed as in Part 1, but CO_2 was injected at the rates in Table 2. In Part 3, the gas was sampled and analyzed for each of the blanket orientations. In Part 4, the blanket orientation that produced the highest CO_2 concentration was used and the gas was sampled and exhausted at the mouth rather than the nose. In Part 5 through 7, the combination of blanket orientation from Part 3 and sample point, *i.e.*, either nose or mouth, was used and the prescribed dead volume was set and then the syringe was operated through the selected stroke volume and frequency. At the end of the tests in Part 5 through 7, the gas in the dead volume was sampled to examine the possibility for CO_2 build-up in the lung dead volume.

2.2 Potential for Carbon Dioxide Build-up.

In this second experiment a carbon dioxide wash-out technique was used to estimate the potential for CO_2 build-up and likelihood of infant mortality. The technique was calibrated by Kemp and Thach[1] by comparing the results to rabbit models of hypercapnia and mortality. The apparatus, Figure 3, were similar to those used in the CO_2 build-up technique except that the carbon dioxide analyzer was replaced with a mass spectrometer to obtain rapid analysis times. The system volume including the tubing and y-connector between the mannequin's face and the syringe was set at 8.0 mL to match Kemp and Thach.

The procedure matched Kemp and Thach. Wash-outs were repeated 7 times each at the nose without the blanket, at the mouth under the bunting bag and with the blanket covering the mannequin and infant carrier at the mouth under the bunting bag. The blanket was placed with the poster facing up and the balloon at the feet. Half-time ($t_{1/2}$) values were determined as per the methods of Kemp and Thach.

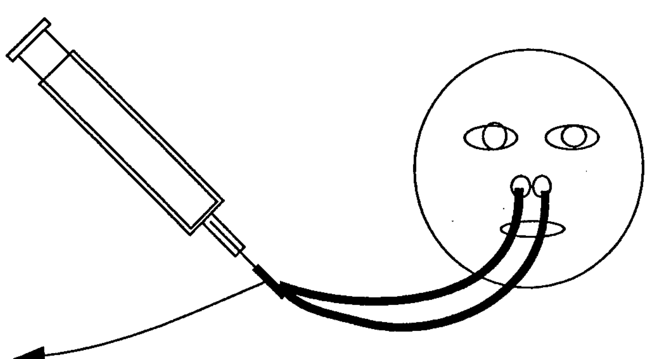


FIGURE 3. Set-up for estimating potential for CO_2 build-up using a wash-out technique. The system volume was 8 mL including the tubing up to the syringe but not including tubing going to the mass spectrometer.

3.0 RESULTS & DISCUSSION

3.1 Variables Influencing CO_2 build-up.

3.1.1 Carbon dioxide build-up at the face.

Gas transport near an infant's face is occurs through a number of different mechanisms. These can include diffusion via concentration differences, thermal convection and gas flow. Gas diffusion on its own will not remove carbon dioxide quickly enough to prevent build-up and rebreathing.[2] Adequate removal relies on convection of expiratory air, and turbulence created by breathing and drafts in the room. [2,3,4] The effectiveness of the carbon dioxide removal depends on other factors such as the difference in temperature between the expired and surrounding air, whether or not heat is exchanged between the blankets and whether condensation occurs, whether the baby is breathing through its nose or mouth, and whether there are temperature differences between air surrounding the baby in its carrier or cot and the air in the room.

In this case, the baby was in an infant carrier in the back seat of a car. A quilted blanket was placed over the carrier to protect the infant from the sun. The environment inside the car was not well defined, *i.e.*, air temperature and humidity, air flow through the back seat, air temperature under the blanket were not known; therefore, it was difficult to compare this case to results from the literature. Rather than try to attempt to recreate a range of environmental conditions, it was decided to vary the respiratory variables and the variables that may have directly influenced the build-up of carbon dioxide, *i.e.*, the coverage produced by the blanket and the bunting bag coverage of the infant's mouth. Possible additional influence of temperature, humidity and room air movement will be proposed here.

Skadberg *et. al.*[4] reported that a near complete barrier is needed to produce carbon dioxide build-up around the face in a breathing infant. This seems to agree with the results of the first set of experiments (para 2.1). With little air movement around the face except the continuous flow of gas to and from the CO_2 analyzer, the CO_2 concentration near the mannequin's face increased in proportion to the rate of CO_2 injection, Figure 4. These levels (5-12%) would certainly have influenced the infant's health. The addition of the blanket to the infant carrier, Figure 5, produced little effect on the CO_2 concentration near the face. There may even have been a reduction in the CO_2 concentration. This reduction may have been produced by the trapping of CO_2 in the blanket which was then transported to the room air. These levels (5 - 6%) would still have been hazardous. Covering the injection/sampling points by placing them under the bunting bag produced dramatic increases in CO_2 concentration, Figure 6, with a maximum value of 18%.

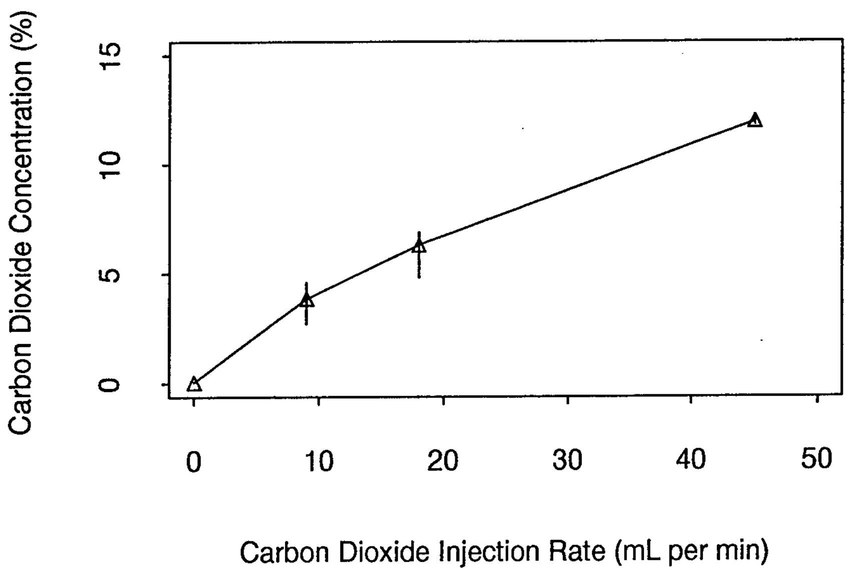


FIGURE 4. Mean carbon dioxide concentration near mannequin's nose with no breathing and no blanket versus carbon dioxide injection into the area. Vertical bars indicate range of three repetitions.

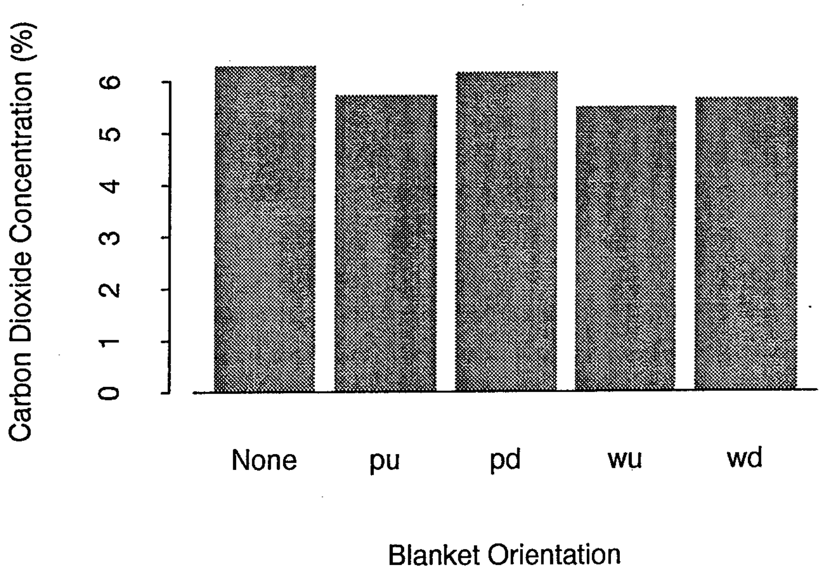


FIGURE 5. Effect of blanket orientation on carbon dioxide concentration near nose with no breathing and 18 $mL \cdot min^{-1}$ carbon dioxide injection rate. None = control condition with no blanket; pu = poster outward with balloon up at head; pd = poster outward with balloon down at feet; wu = wallpaper outward with balloon up at head; and wd = wallpaper outward with balloon down at feet. Data represents mean of three repetitions in each condition.

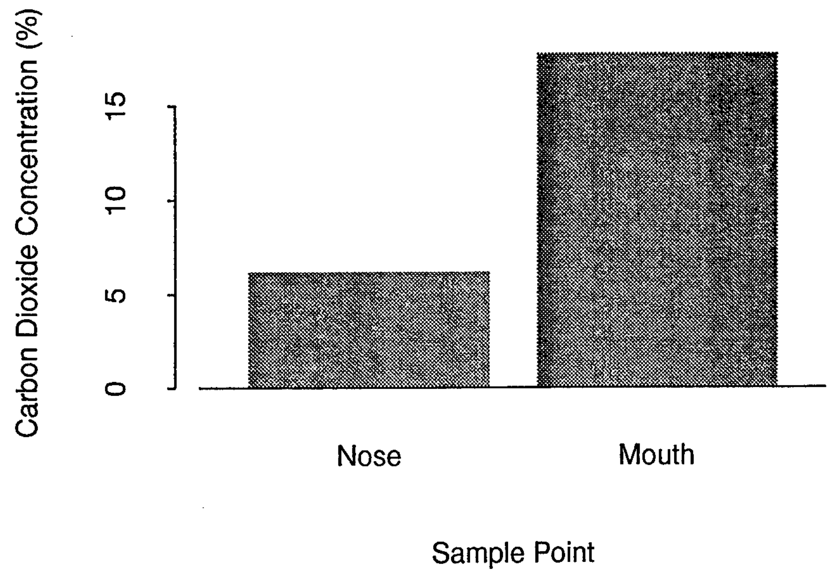


FIGURE 6. Influence of sample point coverage (outside of or under bunting bag) on carbon dioxide concentration with the blanket in the poster outward, balloon at head configuration, no breathing and 18 mL•min^{-1} carbon dioxide injection rate. The nose was not covered by the bunting bag, the mouth sample point was covered. Injection and sample points were adjacent. Data represents mean of three repetitions in each condition.

Consequently, for tests in Parts 5 thorough 7, the blanket was oriented with the blanket with the poster outward and the sample point at the mouth. This produced the highest CO_2 concentrations; however, as predicted by Skadberg *et. al.*[4], the CO_2 concentration near the mannequin dropped significantly to between 0.6 and 1.6% when ventilation was applied, Figure 7. This is still above control values, ~0.06% (see Figure 4 at 0 mL•min^{-1} CO_2 injection rate), which indicates that rebreathing was occurring.

The influence of stroke frequency, dead volume and stroke volume were not as important as the presence or absence of ventilation itself, Figure 7, 8 and 9. CO_2 concentration under the bunting bag in the region of the mouth tended to decrease with increased stroke frequency and volume and increase with increased dead volume. However, the differences were minor with CO_2 concentrations tending to be within 1 and 2%. Whether these levels would have been dangerous for the 45 minutes in the car is not known. But considering that allowable industrial levels for healthy adults are 0.5% for long term exposure and 3% for short term exposure[5], then it is highly likely that exposures in the 1 to 2% range would have been detrimental to a prematurely born infant with a history of cardio-respiratory problems who had just left the hospital after recovering from a respiratory infection.

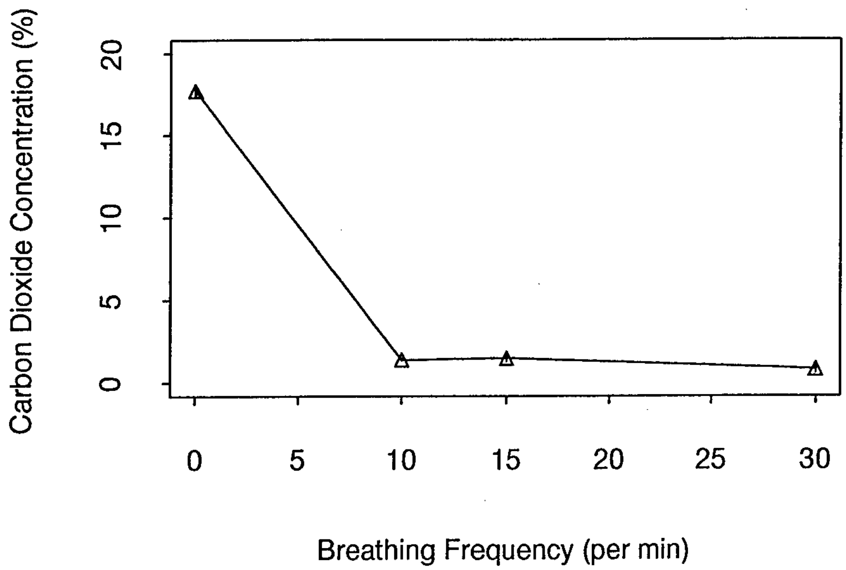


FIGURE 7. **Breathing Effect..** Mean carbon dioxide concentration versus breathing frequency with a system dead volume of 70 mL with the blanket in the poster outward, balloon at head configuration, the sample point at the mouth, a stroke volume of 30 mL and an injection concentration of 4%. Vertical bars indicate range of three repetitions.

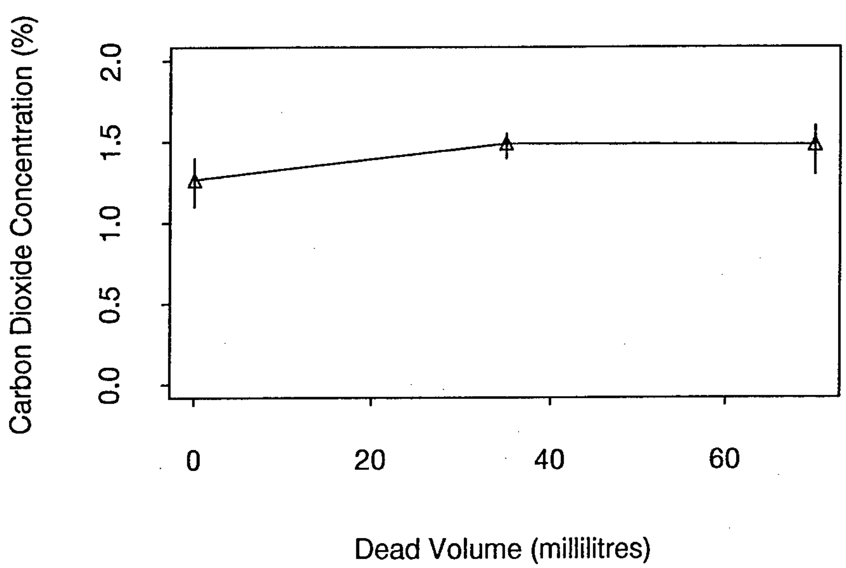


FIGURE 8. **Dead Volume Effect.** Mean carbon dioxide concentration versus syringe dead volume using a stroke volume of 30 mL a stroke frequency of 15 min^{-1} with the blanket in the poster outward, balloon at head configuration, the sample point at the mouth and an injection flow rate of 18 $mL \cdot min^{-1}$. Vertical bars indicate range of three repetitions.

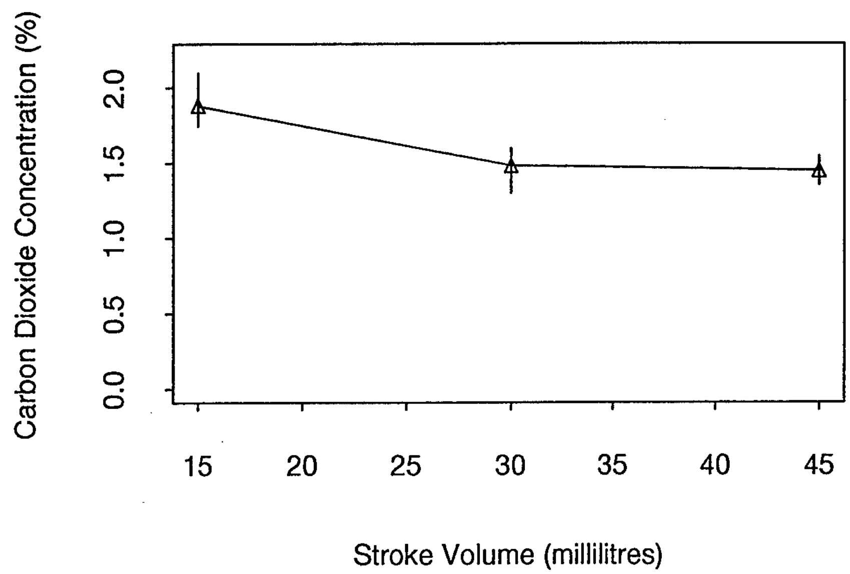


FIGURE 9. **Stroke Volume Effect.** Mean carbon dioxide concentration versus stroke volume using a dead volume of 70 mL a stroke frequency such that total ventilation was 450 mL•min^{-1} with the blanket in the poster outward, balloon at head configuration, the sample point at the mouth and an injection flow rate of 18 mL•min^{-1}. Vertical bars indicate range of three repetitions.

3.1.2 Carbon dioxide build up in the dead volume.

The trends were reversed in the syringe dead volume measured at the end of the ten minute tests, Figure 10, 11, 12. CO_2 concentration in the syringe tended to increase with increased stroke frequency and volume and decrease with increased dead volume. The concentrations ranged from 2.5 to 4%. Whether these values were particularly valid estimations of lung conditions was not determined; consequently, little could be said regarding estimations of CO_2 build-up in the infant's lungs.

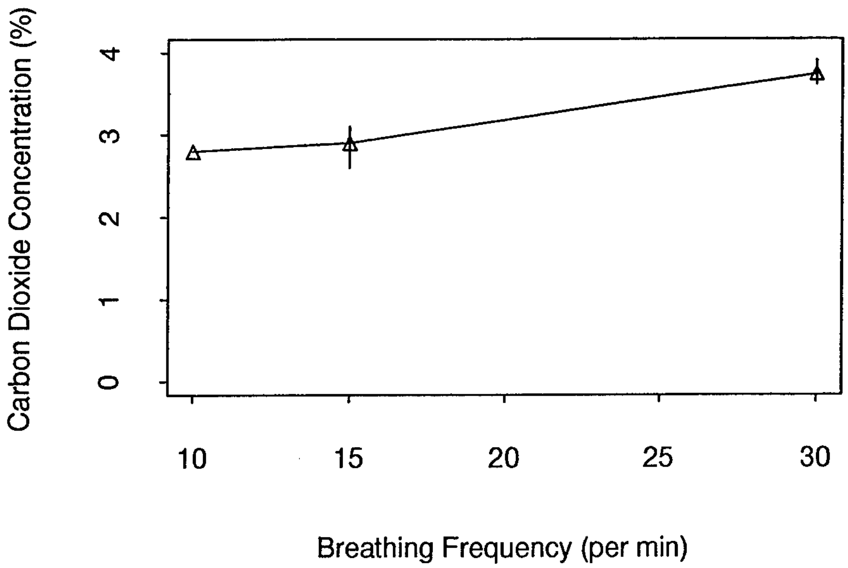


FIGURE 10. Syringe dead volume mean carbon dioxide concentration after ten minutes versus stroke frequency with a system dead volume of 70 mL with the blanket in the poster outward, balloon at head configuration, the sample point at the mouth, a stroke volume of 30 mL and an injection concentration of 4%. Vertical bars indicate range of three repetitions.

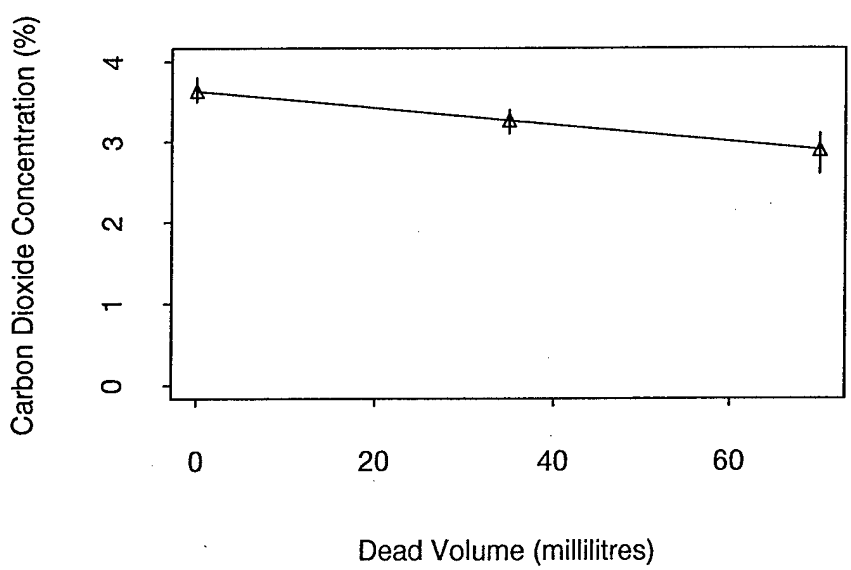


FIGURE 11. Syringe dead volume mean carbon dioxide concentration after ten minutes versus syringe dead volume using a stroke volume of 30 mL a stroke frequency of 15 min^{-1} with the blanket in the poster outward, balloon at head configuration, the sample point at the mouth and an injection flow rate of 18 $mL{\cdot}min^{-1}$. Vertical bars indicate range of three repetitions.

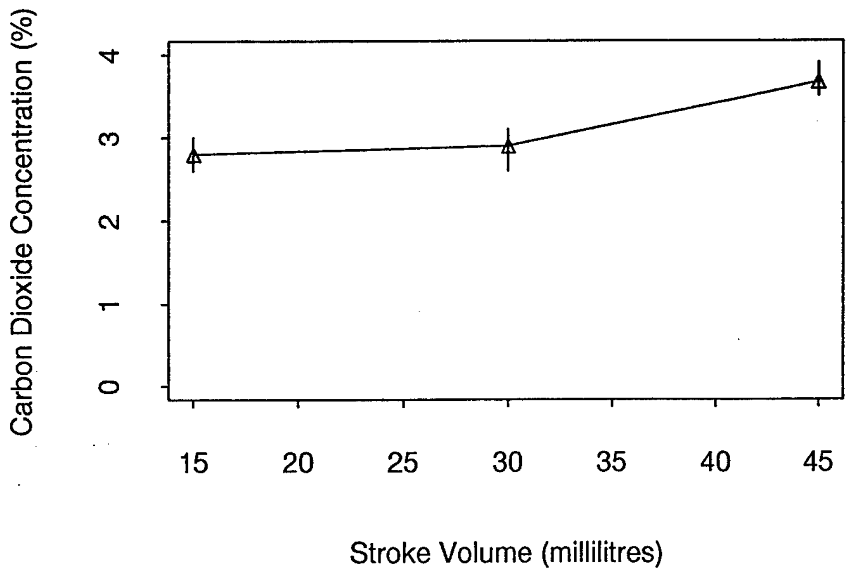


FIGURE 12. Syringe dead volume mean carbon dioxide concentration after ten minutes versus stroke volume using a dead volume of 70 mL a stroke frequency such that total ventilation was 450 mL•min^{-1} with the blanket in the poster outward, balloon at head configuration, the sample point at the mouth and an injection flow rate of 18 mL•min^{-1}. Vertical bars indicate range of three repetitions.

3.2 Potential for Carbon Dioxide Build-up.

In the CO_2 wash-out experiment, the control condition, (Figure 13, Nose) the mean $t_{1/2}$ was 13.1 s which was comparable to the 12.5 s for the mannequin alone that Kemp and Thach[1] reported. The mean $t_{1/2}$ recorded for the mouth under the bunting bag was 14.7 s and for the mouth under the bunting bag with the blanket in place $t_{1/2}$ was 15.5 s. These values were less than the 18.7 s associated with increased Pa_{CO_2}, decreased pH or arterial PO2.[1] Consequently, from this model, it would be estimated that the blanket and bunting bag would not produce potentially dangerous rebreathing. However, the technique was calibrated for a healthy 4-5 kg infant based on data from healthy New Zealand rabbits (4.2 ± 0.4 kg). Therefore, the calibration may not be representative in this case. The increase in $t_{1/2}$ at the covered mouth and with the blanket in place may be significant in this case of a young infant experiencing on-going respiratory trouble.

An additional difference between the two techniques was the use of a fast response (<150 ms) mass spectrometer in this experiment versus the Beckman LB-2 infra-red analyzer. The increased response speed produced more defined peaks and troughs in this experiment, Figure 14, compared to the example shown in Kemp and Thach[1]. In their example, the minimum values remain well above 1% while the mass spectrometer responded quickly enough to show minimum values nearer to 0.5%. A similar comparison of responses would be expected for the peak values. Higher peaks would be expected with the mass spectrometer. On the other hand, the effect of improved response time should be minimal as the slower responding analyzer would also indicate a lower initial CO_2 concentration so that a smaller value would be calculated to determine $t_{1/2}$. Therefore, the only benefit of the faster responding mass spectrometer is to produce a more refined representation of the single exponential decay (Figure 14, dashed line) predicted by Kemp and Thach and expected for this type of washout technique.

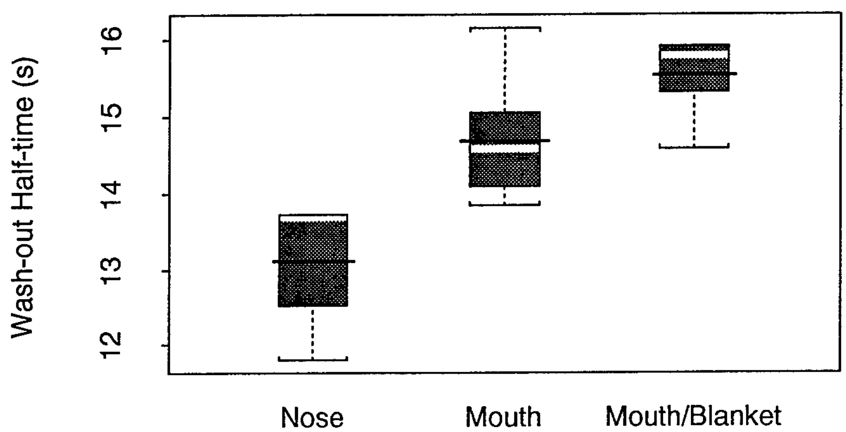


FIGURE 13. Wash-out half-times at the nose and mouth without the blanket and at the mouth with the blanket. Each box plot represents the results from 7 individual tests in each condition. The white horizontal line in the box interior is the median, the black horizontal line is the mean. The height of the box is the difference between the first and third quartile which indicates the spread of the distribution. The dotted lines extend to the extreme data values.

Differences between the car environment and the laboratory environment could have an influence on the results. Increased air movement in the car compared to the laboratory would have reduced the potential for build-up of carbon dioxide. However, the air flow in the car was not known and if the windows were closed and ventilation system shut, the air movement in the car could have been very low, thereby increasing the likelihood of carbon dioxide build-up. If the air in the car was cold the effect is to decrease air movement and increase the carbon dioxide build-up, but the baby was covered with a blanket to protect it from the sun and it was assumed that the car driver would have kept the car warm to protect the child. On the other hand, it can be assumed that the sun was shining on the child (the reason for covering it with the blanket); therefore, solar heating may have been occurring which would have increased the dispersal of carbon dioxide. Cold air is also important because it can cool the warm, moist exhaled breath which would result in increased stability of the gas and less turbulence to disperse the carbon dioxide. Another important factor is the presence of condensation nuclei (*e.g.*, cigarette smoke) that cause condensation in the exhaled air which increases the air's density, increases its stability and again reduces the likelihood of carbon dioxide dispersal. Unfortunately, information regarding these factors is not available in the detail needed to establish corrections to the results found in these experiments. Any estimates made on their effects would only be supposition.

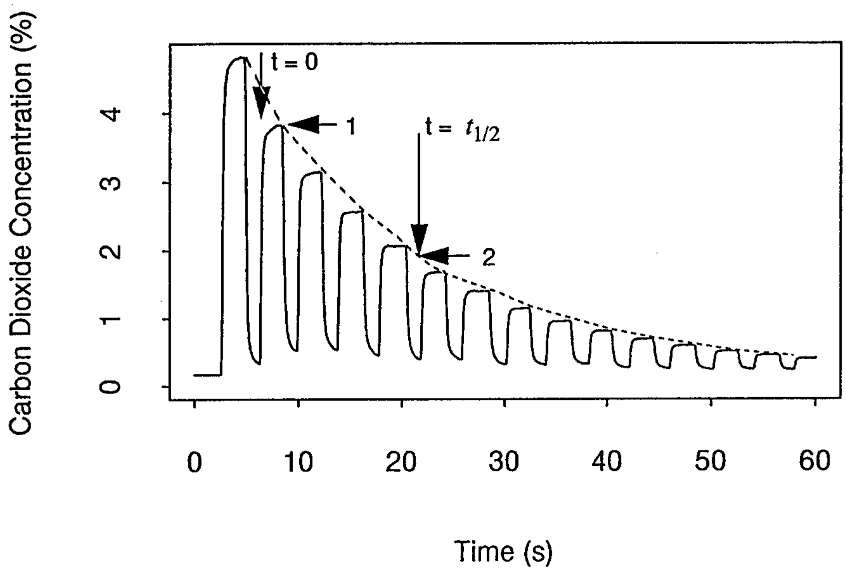


FIGURE 14. Example of carbon dioxide wash-out data. Timing started at arrow marked t= 0. The initial carbon dioxide concentration was established from the end of the first 30 mL stroke exhaust stroke of the syringe (1). The half-time, t = $t_{1/2}$, was the time required for the concentration to drop to 1/2 the initial value (2) along a line interpolated between the peaks.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The experimental methods showed that carbon dioxide build-up in the range of 1 to 2% was possible near the mouth of an infant in a covered carrier. Environmental conditions in the car at the time were unknown so that a confident estimate could not be made of the difference between the laboratory and actual conditions.

The carbon dioxide levels were within the acceptable range for healthy adults; they may not have been for a child who had recently experienced respiratory infection. In any case, the recommendations and findings of other researchers should be re-iterated, i.e., ensure that there is good ventilation in the room and keep thick bedding and tight fitting clothing away the child's face.[1, 2, 3, 4, 6]

5.0 REFERENCES

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Dr. Stephen Wetmore, Coroner, Ministry of the Solicitor General, asked DCIEM to investigate the possibility that carbon dioxide buildup may have been a predisposing factor in the death of an infant. This is an account of the circumstances surrounding the death, the methods used to examine the hypothesis, the results and a discussion with recommendations regarding the results.

The four-month old infant had just been released from the hospital after a serious respiratory infection. He was transported home in an infant carrier in the back seat of the car. The carrier was covered with a quilted blanket to protect the baby from the sun. Upon arrival at home, the infant was not breathing and after some brief resuscitative efforts was rushed to hospital where he was resuscitated in the emergency department. The baby died three days later with the post-mortem indicating pneumonia and tracheal infection.

CO_2 rebreathing has been considered as a causal factor in some infant deaths. The rebreathing is usually associated with the position of the baby's face in relation to bedding, the material and thickness of the bedding and the convective air flow conditions near the baby's face.

Dr. Wetmore provided the infant carrier, the blanket and the baby's clothing. DCIEM developed experimental methods to estimate the baby's possible exposure to carbon dioxide. The potential for carbon dioxide buildup of the bunting bag and blanket combination was also established using a technique developed by Kemp and Thach[1] that quantifies the potential of specific conditions for rebreathing.

The experimental methods showed that carbon dioxide buildup in the range of 1 to 2% was possible near the mouth of an infant in a covered carrier. Environmental conditions in the car at the time were unknown so that a confident estimate could not be made of the difference between the laboratory and actual conditions.

The carbon dioxide levels were within the acceptable range for healthy adults; they may not have been for a child who had recently experienced respiratory infection. In any case, the recommendations and findings of other researchers should be reiterated, i.e., ensure that there is good ventilation in the room and keep thick bedding and tight-fitting clothing away from the child's face.

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Hypercapnia
Carbon Dioxide Rebreathing
Sudden Infant Death
Carbon Dioxide Washout