A review of child car restraint recommendations and information for the transport of premature babies

The University of Western Australia

School of Population Health

Master of Public Health

750.703 Project

Sue Wicks

2005

Supervisor

Dr Rina Cercarelli

Acknowledgements

My thanks go to my supervisor Rina Cercerelli for her encouragement and valued feedback and to my family for putting up with my obsessions with child car restraints and the time I have spent preoccupied with this project.

I also thank the Board of Kidsafe WA for allowing me the time to complete this project and my colleagues for keeping me sane when the world is going mad around us.

Contents

Abstract **v**
Introduction **6**
Purpose of project **7**
Objectives **7**
Methods **7**
Search Results **8**
Restraint of Infants and Young Children **9**
Misuse of child restraints *9*
Australian Legislation *9*
Australian Standard AS/NZS: 1754 *10*
Types of restraints for use by newborn babies *11*
Criteria for optimal fit of harnessing *13*
Criteria for proper installation *14*
Premature infants and child car restraints **14**
Physical fitment issues for premature infants *18*
Respiratory effects of positioning for premature infants *22*
Discussion **38**
Currency and description of restraints *38*
Definitions and significance of events of interest *40*
Policy *41*
Recommendations **43**
Further Research **45**
Methodological Issues *45*
Statement of Participation **48**
Glossary **49**
References **52**

Table of Figures

Figure 1: Traditional style Baby Safety Capsule 12
Figure 2: European style capsules on the Australian market 12
Figure 3: Type A/B (Convertible) restraints in rearward and forward facing configuration 13
Figure 4: Representations of the angle of recline on a forward facing restraint and a rearward facing restraint 14
Figure 5: Interpretation of measurement of degree of recline in infant restraints. 39

Abstract

Infant car restraints are invaluable in reducing death and injury in car crashes. They are however, designed for infants that fit within average size and weight parameters. Some infants, such as premature and low birth weight infants are outside these parameters and consequently may not fit securely in infant restraints. Premature infants may also experience other developmental problems that may place them at risk in infant car restraints.

A search of the literature, peer reviewed sources as well as other available information was conducted in order to identify and review existing recommendations and information related to premature infants and infant car restraints. The initial search was in literature in the last 5 – 10 years, but this had to be extended out to the last 20 years due to the scarcity of papers. A series of studies conducted mainly in the USA and Canada in the last twenty years was subsequently identified and reviewed for relevance and comparison to current Australian Standards infant restraints.

All of the studies reviewed showed that premature, low birth weight and some term infants may experience episodes of apnea, bradycardia and oxygen desaturation in infant car restraints. Premature and low birth weight infants also did not fit securely into the restraints used in the studies.

The restraints used in these studies do not appear to be comparable with current Australian Standards restraints, so further research using Australian Standards restraints is recommended in order to develop policy and procedure for Australian Neonatal Care Units.

A review of child car restraint recommendations and information for the transport of premature babies

Introduction

The value of child car restraints in reducing death and injury to infants and children in car crashes in Australia was well documented in a study by Dr Michael Henderson for the NSW Division of the Child Accident Prevention Foundation of Australia (Kidsafe) in 1994[1]. Current information and recommendations for the appropriate restraint of infants and young children as passengers in cars relate to infants and children who fit within average weight and size measures and within normal developmental parameters. Infants and young children who do not fit within these parameters may require special consideration [2, 3].

Premature infants are one group who often do not fit within the usual weight and size parameters for many child car restraints. With improvements in health care and technology, these premature infants, who in the past may not have survived, are now surviving and are being discharged from hospital much earlier and sometimes at weights less than 2kgs[4]. Child car restraints currently available in Australia are designed for an average birth weight of approximately 3kgs[5].

Apart from size and weight considerations, premature newborn infants have a number of specific developmental issues that may contribute to them being at risk in some child car restraints.

This project had its genesis in concerns expressed by members of staff at the Neonatal Special Care Nursery at King Edward Memorial Hospital for Women in Perth, Western Australia. These concerns related in the first instance to getting proper fitment of premature infants in child car restraints and secondly to oxygen saturation levels of premature infants whilst in child car restraints.

In 2001 there were 252,572 live births in Australia, of which 19,729 (7.8%) were preterm births occurring before 37 weeks gestation. 15,751 (6.2%) of these births were low birth weight babies weighing less than 2500g at birth[6]. For Western Australia in 2002, 8.1% of total births were classed as preterm (less than 37 weeks gestation) and 6.7% of all births were low birth weight (less than 2500g). The majority (59%) of all

preterm births were also <2500g weight at birth[4]. Western Australia's percentage of preterm and low birth weight births is marginally higher than Australia as a whole.

Purpose of project

The purpose of this project is to review the existing literature and other sources for recommendations and information related to child car restraint use for premature infants and the scientific evidence backing those recommendations and information. Of particular interest is the identification of recommendations and information specific to Australia.

Review of the literature is anticipated to lead to the development of a proposal for further investigation of appropriate restraints for premature babies.

Objectives

- Review current literature and other information sources related to appropriate restraint of infants and young children as passengers in cars.
- Review current literature related to any special concerns for premature and pre-term infants as passengers in cars and appropriate restraint systems for them.
- Make recommendations, including a proposed plan for further research on appropriate car restraints for premature and pre-term infants.

Methods

In searching the literature and other publicly available information related to child car restraint use and specific concerns related to child car restraints for premature infants a number of search strategies were implemented.

The key terms “child restraints”, “child car restraints”, “premature babies” and “oxygen saturation” were used to search the following databases:

- Harriet Lane Links
- Informit
- Ovid
- Science Direct

The initial time frame selected in which to search for papers was the last five years but as there were limited results the time frame was expanded to the last 10 years. Due to the limited number of papers meeting all the search criteria, references in identified

papers were also followed up. Consequently the time frame ultimately extended to the last 20 years.

Priority was given to locating papers and information from peer reviewed journals, professional journals or websites and recognised authority sources. Where these were found and identified as fitting the criteria for this review, copies were obtained and read, and where necessary, relevant papers from their references were also identified and obtained.

In addition, for more popular information and for current data and statistics the search terms “child restraints”, “child car restraints”, “premature babies” and “neonatal intensive care units” were also used in Google to search the internet. Only search results from recognised authority sources, such as government and research websites were included in the review.

Criteria for inclusion of articles and other information sources in this review were:

- Specific mention of issues related to child car restraints for premature or low birth weight babies
- Specific mention of oxygen saturation, hypoxemia, bradycardia measurement in premature or low birth weight babies
- Mention of issues related to child car restraint use for babies with specific health issues
- Specific mention of the benefits of child car restraint use

The definition of a premature (or preterm) birth adopted for this review is a birth occurring between 20 and 37 weeks gestation. While the term premature will be primarily used throughout this review, preterm may also appear.

Search Results

Search results are presented in alignment with the objectives of this review. Restraints for infants and young children covers the effectiveness of child car restraints; misuse of restraints; legislative requirements; Australian Standards for child car restraints; types of restraints available for newborns and optimal fitting and installation guidelines. Premature infants and child car restraints covers existing recommendations for the transport of premature infants and the primary issues the existing recommendations are intended to address. As much of the research behind the recommendations is

historical and each builds upon the last, a descriptive summary of each of the studies has been included.

Restraint of Infants and Young Children

Child car restraints have been shown to reduce the risk of death and serious injury in a car crash by up to 70%[1 7]. Infants and children who sustain injuries in car crashes, despite being restrained, generally suffer minor injuries which include bruising from harnessing or seatbelts and lacerations from broken glass[1]. While more severe injures do occur, these are usually the result of severe intrusion into the occupant compartment of the vehicle, particularly in side impacts; invasion of the rear passenger space by collapsing front seat backs and passenger head contact with other parts of the interior of the vehicle[1]. For these more severe injuries, a common factor is the misuse of child restraint devices and systems.

Misuse of child restraints

A number of sources in both Australia and overseas report observed misuse of child car restraint devices and systems[1 8 9 10 11 52]. The most common misuses include incorrect fitment of the restraint to the vehicle; inappropriate selection of restraint for the weight and size of the infant / child who is to use it; incorrect fitment and adjustment of the harness on the child; twisting of the harnessing or the upper anchorage strap webbing.

Australian Legislation

The Australian Road Rules 2000 and the legally enforceable state Road Traffic Codes set out the regulations pertaining to passengers in vehicles. The West Australian Road Traffic Code 2000[12] **Part 16, Division 1, R230** defines **"suitable child restraint"** as meaning: *"a child restraint that is appropriate to restrain the size and weight of the child that is to use it, according to the recommendations of either the relevant version of the standard, or the manufacturer's recommendations."*

For the regulations particularly applying to infants under twelve months of age, **Part 16, Division 1, R 235** states:

"Driver to ensure that children under 12 months of age wear a child restraint

> (*1) A person shall not drive a motor vehicle on a road unless every passenger under 12 months is wearing a suitable child restraint and the restraint is properly adjusted and securely fastened.*

Points: during a holiday period 6; otherwise 3

Modified penalty (in each case) 3 PU

(2) It is a defence in proceedings for an offence against sub-regulation (1) for the person charged to prove that —

(a) the motor vehicle was a passenger car manufactured on or before 1 July 1976 or any other vehicle not required to be fitted with child restraint anchor points and was not, in fact, fitted with child restraint anchor points;

(b) the motor vehicle was a taxi or a special purpose vehicle;

(c) the passenger had a medical certificate at the relevant time and, if required to do so, the medical certificate was produced by the driver; or

(d) at the relevant time, the passenger was not wearing a child restraint because of exceptional circumstances, such as a medical emergency.

[Regulation 235 amended in Gazette 1 Dec 2000 p. 6754; 8 Mar 2002 p. 948.]"

Australian Standard AS/NZS: 1754

In Australia, the joint Australian New Zealand Standard for child car restraints, AS/NZS:1754[13], is a mandatory standard. Australian Standards become mandatory when they are referenced in legislation. The AS/NZS:1754 is referenced in two pieces of Australian legislation: in Federal and State Trade Practices legislation covering the supply of goods and the Australian Road Rules 2000. The combined effect of this referencing is that it is illegal to supply a child restraint that is not Australian Standards certified and that it is illegal to use a child restraint that is not Australian Standards certified.

The Australian Standard for child restraint systems sets the **minimum** requirements for materials, design, construction, performance, testing and labelling that all manufacturers of child car restraints must meet before their product reaches the marketplace. The Australian Standard for child car restraints is recognised as the most stringent in the world.

Some of the unique features of the Australian Standard include:

- Requirement for an upper tether strap to be used in conjunction with the vehicle seatbelt to improve stability and performance of the restraint.
- Requirement for a split crotch strap for restraints that can be used in a forward facing configuration to reduce the risk of genital injury
- The use of a five point harness system
- Dynamic side impact and simulated rollover testing requirements add extra dimension to the testing program for Australian restraints, covering additional possible crash scenarios.

- The use of higher G-forces in dynamic testing.

The following table is taken from the Safe-n-Sound Child Restraint Education Course[14] workbook and shows a comparison of the G forces used in testing under the Australian, European and USA / Canadian Standards.

Dynamic test	Australia	ECE (Europe)	USA / Canada
Frontal	24 – 34 G	20 – 28 G	18 – 24 G
Rear	14 – 21 G	14 – 21 G	No Test
Side	14 – 21 G	No Test	No Test
Inverted	8 – 15 G	No Test	No Test

The test dummies available for dynamic testing of child car restraints for the Australian Standard are:

Dummy	Weight	Approximate Age equivalent
TARU THERESA	4kg	1 month old
TNO $P^3/_4$	9kg	6 month old
TNO P3	15kg	3 year old
TNO P6	21kg	6 year old
TNO P10	32kg	10 year old

Types of restraints for use by newborn babies

The Australian Standard for child car restraints describes three types of restraint suitable for infants from birth up to 9kg or 12kg in weight and approximately 6 months of age. Only two of these types are available on the Australian market.

Type A1 restraints are dedicated rearward facing restraints, suitable for infants up to 9kg in weight and 70cms in length[13 14]. They are commonly known as infant capsules. There are currently 2 designs of infant capsule on the Australian market; the traditional capsule and a newer more European styled capsule.

The traditional capsule first appeared in the early - mid 1980's and consists of two main components; a base which is secured in the vehicle using a standard adult seatbelt and a carry basket which locks into the base. The carry basket component is designed to secure the baby inside it with the use of a five point harness (since 1993) and can be removed from the vehicle. It has high sides and a deep recess in which the infant is placed.

Figure 1: Traditional style Baby Safety Capsule

The newer European style of capsule first appeared on the Australian market in late 2002. It also consists of two main components; a base which is secured in the vehicle by using a standard adult seatbelt and a carry basket which locks into the base. The carry basket in the newer style of capsule has more cut away sides, slightly less angle in the recess and more padding in the cover than the traditional style capsule.

Figure 2: European style capsules on the Australian market

Type A2 restraints are also dedicated rear facing infant restraints, suitable for infants up to 12kg. There are currently no dedicated examples of this type of restraint on the Australian market, although some Type A/B restraints include the mass range of this restraint type.

Type A3 restraints are dedicated infant restraints suitable for infants from birth up to 9 kg and 70cms in length. Type A3 restraints are used transversely across the vehicle seat and allow the infant to lie flat in the restraint. There are currently no restraints of this type available on the Australian market. The Steelcraft Swinger, last manufactured in 1987 in Australia, is an example of a Type A3 restraint.

Combination Type A/B restraints, commonly known as convertible restraints, are suitable for infants from birth up to 18kgs in weight, generally about 4 years of age. As the name suggests, convertible restraints combine the features of a dedicated rearward facing restraint and a dedicated forward facing restraint in one restraint, offering greater

versatility, which perhaps explains their growing popularity. Convertible restraints in their rearward facing mode are suitable for babies from birth up to either 9kg in weight or 12 kg in weight, depending on manufacturer, model and age of restraint. In their forward facing mode they are suitable for babies from a minimum of 8kgs in weight and a recommended minimum 6 months of age up to 18kgs in weight.

Figure 3: Type A/B (Convertible) restraints in rearward and forward facing configuration

Criteria for optimal fit of harnessing

Safe-n-Sound Child Restraint Education Course materials[14] and Kidsafe WA Child Restraint Course materials[15] state that the optimal fit of the harnessing around the baby is so that only one finger can be inserted between the harnessing and the baby's body. This guideline is intended to reduce the chance of an infant being ejected from harnessing that is too loose. To assist in achieving this degree of firmness of fit and to ensure the harnessing has proper contact with the infants' body, the infant should not be wrapped in blankets, sheets or wear very thick, loose clothing when placed in the restraint.

The shoulder straps of the harness should be as close as possible to the top of the infant's shoulders, with no more that 2.5cms variation. In rearward facing mode, the shoulder height of harnessing should be level with or slightly above the infants' shoulder level. In forward facing mode, shoulder height of the harnessing can be up to 2.5cms below or above the infants shoulder level.

The five point harnessing system is designed to offer maximum restraining points around the infants' body over the stronger bony structures; one point at each shoulder, one at crotch level and one point on each hip level, thus enabling restraint of the body vertically and laterally.

Criteria for proper installation

The proper installation of a child car restraint is assessed against the following criteria[15];

- The restraint is configured in the correct mode for the infant / child using it – ie in a rearward facing mode for infants less than 9kgs and approximately 6 months of age or a forward facing mode for infants weighing more than 9kg and over 6 months of age
- The vehicle seatbelt used is the correct seatbelt for the seating position the restraint is occupying; is passed through the correct seatbelt pathway in the restraint and is properly connected and adjusted.
- There is a child restraint anchor point evident in the vehicle and the anchor fitting is assembled, installed and used correctly.
- The upper tether is connected and properly adjusted for the mode of the restraint.
- For forward facing (Type B) restraints, the angle of recline of the restraint is not greater than 45° on a standard vehicle seat with a 15° slope. For rearward facing (Type A) restraints, Britax Childcare Pty Ltd, manufacturers of Safe-n-Sound child car restraints, state that they design to give an angle of recline of 45 – 50° on a standard vehicle seat with a 15° slope.
- There is no excessive sideways movement of the restraint on the vehicle seat.
- The restraint is not wedged into place by the front seats.

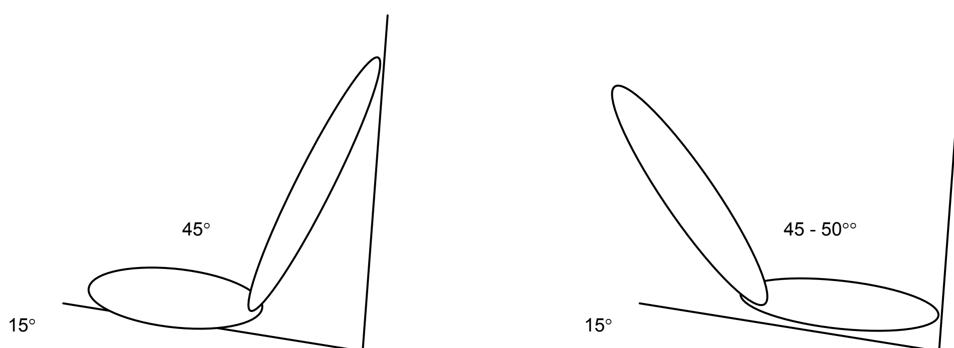

Figure 4: Representations of the angle of recline on a forward facing restraint and a rearward facing restraint

Premature infants and child car restraints

Initial search results identified published Policy Statements by the American Academy of Pedatrics[2 16] and the Canadian Paediatric Society[17] on the topic of child car restraints and premature infants.

The American Academy of Pediatrics has a policy titled *The Safe Transportation of Premature Infants*[16] first developed in 1991 by the Committee on Injury and Poison Prevention and the Committee on Fetus and Newborn. The policy was revised in 1996 and included low birth weight (LBW) babies[2] .

The key issues as described in the AAP Policy are:

- that improved survival rates and earlier discharge (of premature infants) have increased the number of infants weighing less than 2500g who are being transported in private vehicles
- that the American Standard for child car restraint systems contains no minimum weight limit and
- that research has indicated that some premature and low birth weight babies may be subject to (oxygen) desaturation when placed in a car safety seat.

The AAP Policy general recommendations are that:

- babies born prior to 37 weeks gestation should be tested in the car seat they are to use prior to discharge to monitor for possible apnea, bradycardia or oxygen desaturation
- families should minimise travel where infants are at risk of respiratory compromise
- infants with documented desaturation, apnea or bradycardia in a semi-upright position should travel in a supine or prone position in an alternative safety device
- infants who require home cardiac or apnea monitoring should use the equipment during travel
- monitoring equipment should to be safely stowed or secured in the vehicle to prevent it becoming a projectile under hard braking or in a crash situation.

There are also specific recommendations related to the type of restraint and its dimensions, positioning of the infant in the restraint, the fit of the harness around the infant with recommendations for additional padding to improve the fit, the angle of the restraint on the vehicle seat and the placement position of the restraint in the vehicle.

A slightly later Policy Statement by the AAP Committee on Fetus and Newborn, titled *Hospital Discharge of the High Risk Neonate – Proposed Guidelines* [18], identifies four categories of high risk infant. First of the categories is the preterm infant, followed secondly by the infant who requires technological support. The third and fourth

categories are infants who are at risk because of family issues and infants with an irreversible condition which will result in early death.

The recommendations of this Policy in relation to preterm infants' readiness for hospital discharge are that 1) the infant has a sustained pattern of weight gain of sufficient duration, rather than achieving a pre-determined weight; 2) that the infant is able to maintain a normal body temperature, fully clothed in an open bed under normal ambient temperature; 3) that the infant can suckle feed without cardiorespiratory compromise and 4) that physiologically mature and stable cardiorespiratory function of sufficient duration has been established.

The Fetus and Newborn Committee of the Canadian Paediatric Society published a Position Statement in 2000, titled *Assessment of babies for car seat safety before hospital discharge* [17]. This position statement considers the evidence on the magnitude of cardiorespiratory risks for babies in car seats and questions who should be tested; what parameters should be tested; what criteria should be used to determine 'failure' and what should happen if the infant fails.

In considering the evidence and questions, the Committee reviewed the published literature before concluding that:

- Parents should have instruction and supervision in the placement of their baby in a car seat and that the instruction should include emphasis on the support and positioning of babies who are born before term, have a low birth weight or significant cardiorespiratory or neurological problems
- There can be no specific recommendation concerning babies undergoing monitoring before hospital discharge but that with current information, babies in Neonatal Intensive Care Units born at less than 37 weeks gestation or other babies with respiratory or neurological abnormalities are more likely to require monitoring for oxygen saturation while in their car seats before discharge.
- There was no clear definition of significant cardiorespiratory abnormalities.
- Adverse cardiorespiratory events in babies before and after discharge from hospital may not be restricted to the positioning of the baby in the car seat – there may be other devices in which these adverse events can occur
- The costs and benefits of monitoring selected babies in car seats before discharge from hospital and associated changes in care should be the subject of ongoing surveillance and research.

The evidence that contributed to these policy statements extends back to research conducted in the 1980's and 1990's and falls into two broad categories. The first category are simple fitment issues and deal with the question of how to best securely fit a very small infant into a restraint designed for a slightly larger infant. The second category relates to adverse cardiorespiratory events in premature infants in car seats.

Before proceeding further it is perhaps best to define the terms *premature* and *preterm* infant. For consistency, this paper will primarily use *premature* but in many instances the terms *premature* and *preterm* are used interchangeably.

The medical definition of a premature (or pre-term) infant is one born prior to 37 weeks gestation, regardless of weight or size [19]. In Australia, a registrable birth is one where the foetus weighs 400g or more or is 20 weeks or more gestation, where birth weight is unknown [6].

Birth weight is a key indicator of the newborn infant's health. Infants weighing less than 2500g at birth are defined as low birth weight (LBW); infants weighing less than 1500g at birth are defined as very low birth weight (VLBW) and infants weighing less than 1000g at birth are defined as extremely low birth weight (ELBW)[6]. The largest proportion of LBW, VLBW and ELBW infants are those who are born prematurely; the lower the infants' gestational age, the greater the likelihood of very low and extremely low birth weights.

Premature infants face a number of challenges to survival depending on their length of gestation, the maturity and development of organs and body functions and the quality of care available at birth. Many will require resuscitation, assistance with breathing and will require the specialist care available at a Level III Neonatal Intensive Care Unit (NICU). Immature and underdeveloped vital organs often mean that involuntary bodily mechanisms such as breathing are compromised and the infant may require ventilation, monitoring and treatment until such time as these functions have developed fully enough to be spontaneous and sustained.

Apnea, defined as "an absence of spontaneous respiration"[19], is a common condition in premature infants that often requires cardiopulmonary monitoring and results in a prolonged hospital stay. A standard clinical definition of apnea is cessation of inspiratory gas flow for 20 seconds, or for a shorter period of time if accompanied by bradycardia (heart rate less than 100 beats per minute), cyanosis, or pallor. A number of different types of apnea are described[20]:

Central apnea: *occurs when the brain fails to send the appropriate signals to the breathing muscles to initiate respirations.*

Obstructive apnea: *occurs when there is inspiratory effort without airflow; ie the airway is obstructed.*

Mixed apnea: *is when both central and obstructive apnea occur in the same episode*

Periodic apnea: *a normal condition in the full-term newborn characterised by an irregular pattern of rapid breathing followed by a brief period of apnea, usually associated with rapid eye movement sleep.*

Apnea of Prematurity: *is a specific diagnosis. The condition usually resolves between 34 to 36 weeks post-conceptual age.*

Apnea has some specific physiologic effects which include: a decrease in arterial oxygen tension; decrease in heart rate; decrease in peripheral blood flow; EEG changes suggesting Central Nervous System depression, if apnea is severe; increase in venous pressure and decrease in muscle tone[20]. Apnea in the newborn not associated with REM sleep or with periodic breathing can be symptomatic of other more serious conditions.

Physical fitment issues for premature infants

Two papers published between 1985 and 1996 discuss physical fitment issues of premature infants in child car restraints. The earliest paper, by Bull and Stroup (1985)[3], recognises that under the US safety standards in the mid 1980's, there was no specification of minimum weight appropriateness on child car restraints, making it difficult for medical and health professionals to recommend suitable restraints for premature and low birth weight (LBW) infants. They then set out to evaluate specific brands and models of restraint for use by premature infants using an observational study design in which infants weighing approximately 2kg were placed in a representative sample of twelve infant restraints.

It has to be noted that it is exceptionally difficult in 2004 and beyond to be able to determine whether or not the restraints used in this study were actually a representative sample of what was then available in the United States, as both manufacturers and models have changed significantly over time and many of the

models mentioned are no longer produced. In terms of the Australian market at that time, there would have been almost no comparison as there were limited brands and models of child car restraint available in Australia in the mid to late 1980's.

The variables measured by Bull and Stroup were the ease and ability of the restraint to securely and comfortably position the infant and measurement of the physical dimensions of the restraint from seat back to crotch strap and seat bottom to lowest shoulder strap level to enable comparison of the restraints. There are little specific criteria provided in this study as to what constitutes "secure and comfortable" positioning of the infant other than that the infant is not able to "slouch" in the harnessing.

None of the sample restraints in this study were suitable without some modification which added extra padding down the sides to support the head and body of the infants being tested and in some cases between the crotch strap and the infant, to prevent "slouching".

Bull and Stroup recommend that modification of a child car restraint may also include the addition of a retainer strap between the shoulder harness straps to keep them closer together to avoid the small infant being ejected from the restraint in an impact. This practice is not recommended by Australian manufacturers due to the risk of the device sliding up the harnessing in an impact and becoming a potential asphyxiation hazard.

The harnessing configuration of the restraints in this study is not described by the authors however photographs of infants in the sample restraints are included and reveal that two of the modified restraints used have only a three point harnessing system, which would offer little or no support or restraint at the infant's hip level.

Many restraints with this harness configuration have the harness connection point well to the front of the seat bottom, which would mean the distance from seat back to the crotch harness is almost the entire width of the seat bottom, thus the finding that some restraints and infants required additional padding at the crotch strap to prevent them slipping forward. This configuration is not seen in Australian Standard child car restraints and is less common now in American and European standard restraints.

Restraints with a lap pad or T-shield were found to be completely unacceptable for use by premature and LBW babies as the pad or shield device came into direct contact with the face or neck of the infant.

Bull and Stroup reiterate that medical and health care professionals should encourage parents of premature and LBW babies to use a child car restraint from the beginning. They recommend that health care professionals should provide parents of these infants with suggestions for suitable modification of their restraint. They also recommend that all infant restraints should be rear facing, whether placed in the front or rear seat of the vehicle, and that infants should remain rear facing for as long as possible as this positioning offers greater support for the infant's head, neck and back in a frontal crash. It is also suggested that parents be encouraged to sit beside the infant to allow for observation of breathing and colour.

There are some additional valid comments about the lack of suitable test dummies for dynamic testing of restraints for LBW babies, which leads to a recommendation for the development of low weight anthropomorphic dummies and dynamic testing procedures. These comments still have validity today, some twenty years later, when the proportion of premature and LBW infants surviving is even higher than it was in the 1980's yet as has been seen with the test dummies that are available for dynamic testing for the Australian Standard, the smallest is 4kgs or the approximate equivalent of a 1 month old infant.

A 1988 study by Bull, Weber and Stroup[21] further examines the issue of suitable car restraints for premature and LBW infants. In this study, Bull *et al* conducted dynamic testing of a sample of child car restraints, including a car bed, with a newly developed anthropomorphic dummy in a crash test laboratory. The anthropomorphic dummy developed specifically for this research simulated a 2.1kg infant in size and shape, with the weight distribution being 25% in the head and 75% in the torso of the dummy. This weight distribution may be an appropriate distribution but is contradictory to other information that indicates that children up to 2 years of age are "top heavy".

The study methodology required that four conventional rear-facing infant car restraints previously identified by Bull and Stroup[3] as being suitable for use by premature infants, were dynamically tested in a crash laboratory. During the study the LBW dummy was placed in each of the restraints, with the harness fastened and adjusted but without the additional padding previously recommended by Bull and Stroup. Each sample restraint, with the dummy harnessed in place was then secured in a rear-facing position on a

crash sled and crashed into a rigid barrier at 30mph (~50kph). For each of the four rear-facing restraints tested, the LBW dummy was effectively restrained by the harnessing of the restraint.

This study also included dynamic testing of a car bed system identified as the “Swinger”, which although identified as being of German manufacture, looks, from included photographic images, similar to a restraint also known as the “Swinger” sold in Australia during the 1980’s under the Steelcraft name.

For the testing of this restraint, both a 7.7kg (6 month) dummy and the new 2.1kg dummy were used. The major differences between the Swinger restraint and the other restraints tested are that the Swinger fits transversely on the vehicle seat and that rather than having an internal harness, the infant is held in place by a sleeping bag style system which attaches to the inside edges of the bed.

In the testing of this restraint system, the restraint was crash tested first with 7.7kg dummy in place, then with the LBW dummy with rolled towels added to the inside of the bag. The authors determined that this restraint system was also effective in restraining the LBW dummy but observed that the restraint did not complete its rotational action under the test crash conditions, surmising that the lower weight of the dummy affected the inertia required for the action to complete. The authors then constructed a smaller “baby bag” for the Swinger and re-tested the restraint under the same conditions, this time demonstrating effective restraint of the smaller dummy and proper rotation of the restraint.

The authors conclude from this study that the car bed style of restraint may be useful for infants who have respiratory compromise but that parent observation of the infant is easier if a conventional restraint is used and placed beside the parent.

Both these studies demonstrate that child car restraints are effective in restraining premature and LBW infants, but that for the restraints used in these studies and which were available at that time, there was need for modification to achieve better fit and support of the infant. The findings and recommendations of both these studies contributed to the development of the AAP and Canadian Paediatric Society’s policy on safe transport for premature and LBW infants and their recommendations regarding physical dimensions of restraints and the additional padding that can be used to better position premature and LBW infants.

Respiratory effects of positioning for premature infants

Over the years a number of concerns have been expressed regarding the respiratory effects of placement and positioning of premature infants in child car restraints. While the previously mentioned papers focussed primarily on the physical fitment issues for premature and LBW infants, they were also aware of concerns for respiratory compromise for these infants in child car restraints.

Nine studies related to the respiratory effects of placement and positioning of infants in child car restraints were identified by the search strategy and inclusion criteria. For the purposes of this paper, it is useful to descriptively summarise the studies chronologically from earliest to most recent before undertaking an analytical review.

Risk of hypoventilation in premature infants in car seats. 1986

The earliest study, by Willett *et al*[22] (1986), examined a sample of 30 newborn infants for respiratory compromise before, during and after placement in a child car restraint. The sample of 30 infants consisted of 12 premature infants with a history of apnea of prematurity, 8 premature infants without observed apnea and 10 full term infants.

The study took place over a five month period in late 1985 and was undertaken in the clinical setting of the NICU. Oxygen saturation, ECG and pneumocardiogram recordings were made for each infant, during the three phases of the study. Alarm limits were set for bradycardia at 80 beats / minute and apnea >20 seconds. Infants were placed in a prone[*] position in an open crib for 30 minutes to obtain baseline measures, then placed in a child car restraint for a further 30 minutes, then placed back in the crib in a prone position for a final 30 minutes. The observation period was a continuous total of 90 minutes per infant. The child car restraint used was one of the makes and models recommended by Bull and Stroup in their 1985 study and rolled blankets were used per their recommendations to prevent slouching or lateral slumping of the infant.

Using this methodology, Willett *et al* found that there were significant differences between the three groups of infants studied. The premature infants with known prior apnea of prematurity and the premature infants without previously observed apnea all showed significant decreases in oxygen saturation <90% and had significantly greater time with oxygen saturation <85% while in the child car restraint. These two groups also took longer to recover to a "normal" reading than did the full term infants, once

[*] See Glossary

removed from the child car restraint and had more time with oxygen saturation <85% in the recovery phase.

No infant recorded either short or prolonged apnea during the observation period although one infant with previously known apnea had a prolonged period of periodic breathing during the recovery phase of the observation period, not associated with decreased oxygen saturation. Of the 12 premature infants with previously known apnea, four recorded bradycardia associated with oxygen saturation <80% whilst in the child car restraint and one premature infant without previously known apnea recorded an episode of bradycardia. Premature infants showed significantly greater oxygen desaturation whilst in the car restraint against their own baseline measures and when compared against the other groups.

Willett *et al* conclude that premature infants may be placed at risk of hypoxia* and ventilatory compromise in the child car restraints available at that time. They go on to discuss a perceived dilemma faced by medical professionals, particularly at a tertiary care centre, who must either recommend the use of a child car restraint that may result in oxygen desaturation and bradycardia in premature and LBW infants or recommend that the infant be held by a parent during car travel, knowing that this mode of transport for infants under 6 months of age at that time and place carried significantly greater risks of death and serious injury if involved in a car crash.

These authors recommend the development of restraints designed specifically for LBW infants and the monitoring of premature and LBW infants in their chosen car restraint prior to discharge from hospital.

This study and its recommendations were also key contributors to the development of the AAP policy for safe transport of premature infants.

The study design used allowed each infant to act as their own control and also enabled between group comparisons to test if prematurity with apnea, prematurity alone or neither of these were factors for oxygen desaturation and bradycardia in child car restraints.

The other aspect of this study that needs to be noted is that the testing was static. It was undertaken in the NICU and no information is provided on how or where the restraints were placed; the specific degree of recline of the restraint (other than semi-

* See Glossary

upright) or the surface it was placed upon for the testing. If, as Willett *et al* suggest, forward slumping of the head may lead to obstructive apnea, then these factors are important to know.

Ventilatory changes in convalescent infants positioned in car seats. 1989

To further investigate the apparent respiratory compromise of premature and LBW infants in child car restraints, Willett[23] *et al* conducted a further study in 1986 - 87, comparing convalescent full term infants with premature and LBW infants, using a similar methodology as in their previous study.

The study population in this subsequent study were infants admitted to the NICU at University Hospital, Nebraska over a twelve month period, October 1986 – September 1987. In the previous study, inclusion criteria were gestational age at birth <37 weeks, convalescent status with anticipated discharge home within 72 hours and no respiratory distress or requirement for supplemental oxygen at the time of the study. In this subsequent study, the inclusion criteria were convalescent status with anticipated discharge home within 72 hours and length of NICU admission more than 7 days.

The study sample for this subsequent study consisted of 62 infants, 31 of whom had a gestational age at birth of <32 weeks, 22 had a gestational age at birth of 32 - 36 weeks and 9 were considered to be full term infants, having a gestational age at birth of >36 weeks.

A wider range of variables were measured in this study than in the previous study. ECG recordings, chest wall and abdominal wall impedance was measured, nasal airflow and oxygen saturation (oximetry). In addition, pulmonary function tests were performed on each infant between each phase of the study. Some infants were followed up over a longer period of time, although there is little detail on this group other than a mention of one infant who suffered a respiratory arrest whilst undergoing repeat observation in a child car restraint at 3 months of age and 2.8kgs in weight. This particular infant apparently continued to have abnormal recordings until 8 months of age.

All the infants in this study group, whether premature or full term had some form of clinical condition that required care and treatment before they were well enough to be discharged home. The more premature infants had lower birth weights, longer hospital stays and more episodes of apnea of prematurity than their slightly older companions.

In effect, these were all compromised infants, so any differences observed could reasonably be attributed to gestational age at birth.

This study found that all of the infants in the study sample had significantly more time with oxygen saturation <85% and more episodes of short apnea whilst in the car seat. Sixteen (26%) of the 62 infants had bradycardia, desaturation or apnea that required intervention during the car seat phase with the study being terminated for 3 infants due to these problems. No full tern infant was found to have abnormal results whilst in the child car restraint.

Of the sixteen infants that required intervention during the period of observation in a child car restraint, 10 had multiple episodes of oxygen desaturation <85% and in those 10 infants there were 11 episodes of desaturation <80%.

Of the sixteen infants who had clinical symptoms in the car seat phase of the study, 11 underwent repeat testing for trend oximetry for 30 minutes in the child car restraint in each of two more reclining positions. The paper does not describe the degree of recline for any of the testing, other than a statement that the position of recline used was that recommended by the manufacturer for newborn infants. It is not until this mention, almost in passing, in this paper that there has been any mention of different recline angles for the restraint used in the testing.

One finding of this study that appears to have surprised the researchers themselves was that the pulmonary function test results for 50 of the 62 infants studied found that pulmonary mechanics improved whilst in the child car restraint.

This study concludes that some premature infants will experience respiratory compromise in a child car restraint; that respiratory difficulties in a child car restraint are most likely multifactorial and may be different for individual infants. The authors state that they had not been able to identify predictive factors for respiratory compromise other than prematurity and recommend screening for respiratory compromise of premature infants in the car restraint the parents intend to use prior to discharge from hospital.

This study also includes some discussion on the possible effects of greater recline angles for premature infants and the use of car beds to enable the infant to lay flat whilst travelling. The authors suggest that an improvement in oxygen saturation observed in this study may have been due to a greater recline angle of the restraint.

One thing that this study does not make entirely clear is the number of positions the restraints used have or whether they are intended to be used in a rearward or forward facing mode. Current Australian Standards restraints suitable for newborn infants have only one recline position in the rear facing mode and generally only two positions in the forward facing mode – upright or semi-reclined.

The physiologic effects of positioning premature infants in car seats. 1990

Concerns that the studies by Willett[22 23] *et al* utilised only a single, unspecified but semi-upright recline position for the testing of premature infants lead to a study by Smith and Turner[24] at Madigan Army Medical Centre, Tacoma, Washington, in 1990 which set out to examine the physiological effects of different angles of recline for premature infants in child car restraints.

This study used a convenience sample of 14 premature infants, born between 28 and 35 weeks gestation who were inpatients in the NICU at the army medical centre. At the time of the study, these 14 infants had a post-conceptual age of 35 – 37 weeks and weighed between 1,590 and 2,730gms. The eligibility criteria for inclusion in the study were that the infant be within 96 hours of discharge, have had no documented apneic or bradycardic episodes during the previous 6 days and not require supplemental oxygen or medications. Bradycardiac episodes were defined as heart rate <90 beats / minute.

The variables measured were oxygen saturation, heart rate, respiratory rate, blood pressure, colour, temperature and tone. Measurements for all variables except colour and tone were made at two minutes intervals throughout the observation period on each day. The observation period was 90 minutes on each day of the three sequential days of the study, divided into three 30 minute periods of observation. The infants were randomly assigned to one of the three child restraint recline positions, 95°, 110° and 140° on the first day of observations and then randomly assigned to the remaining recline positions on the subsequent two days of the study. Baseline recordings were made whilst the infants were lying prone on a warmer for 30 minutes. The infant was then placed in the infant restraint and observed for 30 minutes before being returned to the warmer for a final 30 minutes. Obtaining a baseline measures allowed each infant to act as their own control.

In the restraint, infants were positioned using rolled blankets to prevent slouching per the recommendations of Bull and Stroup and then photographed so that similar

positioning could be achieved for each of the observation periods. The restraint used was a dedicated infant restraint – ie only suitable for an infant from birth to 20lb (~9kg) in weight.

This study found that 3 of the 14 infant's experienced apneic and bradycardic episodes while in the most upright (95°) of the child restraint positions but that only one of these required observer intervention in the way of repositioning to resolve the apnea and bradycardia. The remaining 2 infants were able reposition themselves sufficiently for the conditions to self-resolve.

Other findings were that there were no significant differences between baseline and recovery period data for each testing period and no significant differences in respiratory effort or oxygen saturation values between the three restraint recline positions. There were, however significant differences in mean arterial pressure and heart rate between the most upright position (95°) and the more reclined positions. No significant differences were found between the 110° and 140° recline positions. In the most upright position, heart rates increased from a mean 165 beats / minute to an average 181 beats / minute after 8 minutes in the child car restraint and mean arterial pressure rose from a baseline of 39-41mmHg to 44-53mmHg which was sustained throughout the time in the child car restraint.

Smith and Turner note that while they did not observe oxygen desaturation in the infants they studied as Willett *et al* did, they did observe lateral slouching of the head, which they hypothesis could lead to airway obstruction and hypoventilation if not corrected. However, they did not defined what their criteria for assessing oxygen desaturation was and report oxygen saturation values ranging from 82% to 99% across the three recline angle positions. Mean oxygen saturation in the 95° recline position was 89%, while for the 110° and 140° positions, SaO_2 saturation values did not fall below 87%.

Smith and Turner conclude that premature infants may tolerate a 95° recline position less well than the 110° and 140° recline positions and that parents should be encouraged not to use the most upright of positions for their premature infant. They recommend that infant car restraints should face rearward in the car; that where possible adults observe the infant during travel for lateral slouching of the head; and that foam inserts be used to provide better positioning of the head and body.

Also acknowledged is that the physiological effects of positioning of premature infants in car seats in this study have been investigated under static conditions, so the effects of motion or vibration on a premature infant's cardiorespiratory effort are still unknown.

This study demonstrated that a greater degree of recline in an infant car restraint is potentially better for premature infants.

Monitoring premature infants in car seats: Implementing the American Academy of Pediatrics policy in a community hospital. 1993

Bass *et al* [25] report their experiences in implementing the American Academy of Pediatrics policy on monitoring of premature infants in car seats before discharge in a community hospital with a Level II NICU.

There was a larger population available for this study to sample from as the hospital involved had approximately 2,200 births annually. Over a 15 month period from November 1990, monitoring of infants <37 weeks gestation at birth in car seats was implemented.

Eighty-seven infants between 26 and 36 weeks gestation at birth were monitored for oxygen saturation, apnea and bradycardia in the car seat they were to use on discharge. Monitoring took place 24 hours before the infant was to be discharged from the hospital. Pulse, respiration and oxygen saturation were monitored for a period of 90 minutes while the infant was in the restraint in the recline position most suitable for infants. Oxygen desaturation <90%, apnea for >20 seconds and bradycardia at <80 beats / minute were recorded. Any repositioning or stimulation required was also noted and the testing was terminated if the symptoms persisted.

This study found that 18.4% (n=16) of the 87 infants monitored had abnormal results. The 16 with abnormal results consisted of 21.2% (n=7) of 33 neonates of 36 weeks gestation and 16.7% (n=9) of 54 neonates of ≤35 weeks gestation. Oxygen desaturation as low as 66% was observed in the 36 week infants and as low as 70% in the ≤35 week infants.

In addition to the 87 premature infants monitored, 9 neonates of 37 – 38 weeks gestation were also monitored at the request of their doctor. The requests for observation were based on LBW (n=4), cyanotic / dusky spells during feeding (n =3) irregular heart rate (n=1) and unknown (n=1). Only one of these infants had an abnormal result, with the infant recording desaturation to 80%, apnea and bradycardia

in the car seat. Further investigation of this infant revealed significant episodes of central apnea and frequent episodes of bradycardia at 50 – 70 beats / minute leading to the infant being treated with oral theophylline.

Bass *et al* discuss the issues that they found in implementing the AAP Policy in a hospital other than a major tertiary centre. The key issues mentioned were:

- Educating doctors that monitoring in the car seat was an accepted standard of professional care, to obtain their support
- The necessity for medical staff policies that linked to both the AAP Policy and hospital policy, which defined the roles of nursing staff and doctors
- Parental compliance, citing that many parents brought the car seat in late or unassembled and were impatient for discharge
- Concerns regarding liability for staff if a restraint was assembled incorrectly and for the hospital for false negatives.

This latter concern was outweighed by the perceived liability of not testing at all in the context of a prior experience of the death of a premature infant in a car seat on the way home on the day of discharge. In all the studies reviewed, this is the only mentioned case of the death of a premature infant whilst in a car seat.

Bass *et al* conclude that a monitoring program can be implemented in a non-tertiary hospital provided that there are appropriate medical staff policies, nursing procedures and administrative support to deal with logistics.

Oxygen desaturation of selected term infants in car seats. 1995

As a result of identifying one term infant that "failed" the car seat monitoring in the previous study, a subsequent study by Bass[26] *et al* considered whether some term infants may also be at risk of oxygen desaturation and or apnea in a child car restraint. In this study, term infants who, in the judgement of their paediatrician, were at risk of oxygen desaturation or apnea were monitored for a period of 90 minutes in a child car restraint, with data recorded for oxygen desaturation, apnea and bradycardia. The twenty eight infants monitored between March 1992 and April 1994 consisted of 14 born at 37 weeks gestation and 14 born at >37 weeks gestation. The most common reasons for requesting the car seat testing was LBW (n=8), followed equally by genetic disorders (n=4) and dusky / apneic / SaO2 desaturation in the nursery (n=4).

This study found that 28.6% (n=8) of the monitored infants had periods of oxygen desaturation <90% and another 17.8% (n=5) recorded oxygen desaturation between 90 – 93%, considered in this study to be a borderline result. All four infants monitored

because of genetic syndromes included in this study had abnormal results, as did two term infants observed to be apneic after discharge from the nursery. Five of the infants with borderline results were re-tested in an alternative car restraint (Cosco Dream Ride car bed); three of these had normal results on re-testing.

From this study, the researchers conclude that select term infants, in this case, infants with genetic syndromes and infants with observed apnea, may be at risk of oxygen desaturation in an upright car seat. While a period of monitoring in a car seat before discharge is recommended, these authors recognise the impracticality and cost of implementing a universal screening program and so recommend, as an alternative, that infants should be routinely transported in readily available supine position car seats in the early months of life.

Premature infants and car seat safety. 1996

A study at the Winnipeg Health Sciences Centre in 1996 by Hamelin[27] *et al* also showed that premature and LBW infants are at risk of desaturation in a child car restraint. This study reported that the highest rate of "failure" (16%) occurred in infants who were both <36 weeks gestation and <2,300g. The infants most vulnerable appeared to be those who were <2,300 g at discharge.

A convenience sample of 161 infants was monitored with a cardiorespiratory monitor and oximeter for apnea, bradycardia and desaturation. A "pass" was defined as no apnea >20 seconds, no bradycardia <80 beats / minute or no SaO^2 saturation level <85% during the monitoring period. Infants were monitored for a minimum one hour or the length of time to travel home (maximum 2.5 hours) in their personal car restraint, however if parents provided a convertible restraint they were advised to purchase or hire a dedicated infant restraint.

Infants were eligible for inclusion in this study if they were able to maintain body temperature without an external heat source; could feed from breast or bottle without supplementation; had a satisfactory sustained weight gain and a 72 hour period with no recorded episodes of apnea or bradycardia.

This study appears to be the first to recognise the contributory role of the vehicle seat in the recline angle of the infant restraint as the study protocol entailed ensuring initial compliance with manufacturer's recommendations to have 80% of the base of the restraint in contact with the vehicle seat. It was noted that for most infants (97%) this immediately required modification as the infants' head dropped forward to the chest,

due to a reduced angle of recline under the effect of the slope of a vehicle seat. The modification implemented was to place padding under the base of the restraint to “lift” one end of the restraint, so creating a more reclined position (45° or 30° from the horizontal) for the infant. Eighty nine percent of the sample “passed” the car seat test with these modifications. The infants who “failed” the testing were all ≤36 weeks gestation at birth and the highest rate of “failure” was found in infants who were both <36 weeks gestation and <2,300g at discharge.

Also noted in this study was the need to add extra padding for side support for 96% of infants and extra crotch support for 76% of infants as per the recommendations made by Bull and Stroup [3] in 1985.

In discussing the finding that 97% of restraints needed padding under them to adjust for the slope of the vehicle seat and make the angle of recline more suitable for premature infants, the authors also discuss the importance of not modifying the angle of the child restraint to the point where the infant’s safety is compromised; a recline angle of greater than 150° is less likely to distribute the deceleration forces of a crash evenly over a broader area of the infant’s body, putting the infant at risk of head and neck injury or of being propelled out of the restraint in a crash.

At the time of this study, car beds as recommended by Bull and Stroup were not approved for use in Canada. Hamelin and Overly suggest that this left health professionals with no option but to discharge at risk infants knowing they may be at risk in their car seat or delay discharge until they were larger and more mature. With the financial pressures on health care systems, delaying discharge is less likely to be an option as time goes on.

Hamelin and Overly conclude that their study confirms that tiny, premature infants are vulnerable to respiratory compromise during travel; that some will experience significant problems despite appropriate precautions and that as a consequence, parents of at risk infants be advised to limit travel until their infant is older and larger. They also support the recommendations of Bull and Stroup for additional padding to support these small infants as well as their own recommendation that many restraints require some padding under them to increase the recline angle of the restraint.

Apart from the dynamic testing conducted by Bull *et al*[21], this is the first study that appears to attempt to account for real-life positioning of infant restraints in vehicles and the effect that this may have on the infant being transported. All previous studies of this

type have been conducted in the clinical setting of the NICU or health care facility, with the infant restraint placed on a flat, stable surface for the duration of the monitoring period. Whether this study was conducted inside the hospital using a dummy vehicle seat or actually conducted in the parent's car remain unclear. The reality is that vehicle seats are not flat and as Smith and Turner[24] identified, the effect of vehicle motion on a premature infant's cardiorespiratory system is unknown.

Predischarge car seat safety study for premature infants. 1996

A comparison to Bass[25] *et al*'s discussion of implementing the AAP policy for the transport of premature infants is a report by Young *et al*[28] on their experience of implementing the AAP Policy in a Canadian Level III NICU.

This study reports the findings on 141 infants studied, 18 of which were excluded from analysis due to incomplete recordings. Gestational ages at birth for the infants ranged from 26 – 36 weeks with birth weights ranging from 380g – 3225 g. At the time of the study, the infant's adjusted ages (post-conceptual age) ranged from 34 – 41 weeks. The study was conducted 48 – 72 hours prior to discharge. Premature infants were considered ready for discharge if they were feeding well by breast or bottle every 3-4 hours; had gained weight for 5 days or more with a gain of 10 – 20g on 3 or more of those days; were able to maintain temperature in an open crib for 24 hours, have cardiorespiratory stability with resolved or controlled apnea; medications were at therapeutic levels; parent education objectives were met and that the parents were prepared, willing and able to continue care.

Infants were monitored for 90 minutes each in both a crib and the car seat they were to use on discharge, for end-tidal carbon dioxide, continuous pulse oximetry, pulse heart rate, heart rate and respiration. Monitoring was set to detect episodes of oxygen desaturation <88%, bradycardia at a 30% fall in heart rate and any episode of central, mixed or obstructive apnea. Two or more events of more than 10 seconds duration were regarded as criteria for failure.

Twenty four percent (n=29) recorded failures according to the study criteria. All of these infants experienced desaturation in their car seat, 12 of them experienced apnea and 7 infants experienced a fall in saturation during periodic breathing. The infants who "failed" were more likely to have had a diagnosis of apnea of prematurity. For 18 (62%) of the 29 infants who recorded failures, desaturation was corrected immediately by decreasing the angle of recline of the restraint to 30° (from the horizontal). Of the 29 infants who "failed" in the car seat part of the study, 8 also "failed" in the crib part. Only

one infant who “failed” the crib part of the testing “passed” the car seat part. The infants who “failed” the car seat test had lower baseline saturation (92.7%) in their car seat than did the infants who passed (96.7%). The interesting thing about this statement is that it is not described how a baseline SaO^2 saturation value was obtained for the car seat observation – was the baseline value derived from recordings of the first few minutes after the infant was placed in the car restraint or was it obtained from the observation period in the crib?

This study found that there did not appear to be a relationship between “pass” or “fail” and the type of car restraint but that pass or failure appeared to relate more to the degree of recline of the restraint.

The length of observation time in the car seat is discussed by these authors as the AAP policy does not specify the length of observation time; this omission is also discussed by McMillan[37]. They go on to state that their study chose to use a 90 minute observation period, as this reflected real-life time for travel home and that there was precedence for this length of observation through the studies of Willett *et al*[22 23] and Bass *et al*[25 26]. They also state that “unlike other studies, they also evaluated infants in their crib”. A curious statement to make when the studies by Willett *et al*[22 23], Bass *et al*[25 26], and Smith *et al*[24] all included a period of observation in a “resting” state, either in a crib or infant warmer. The total length of observation in these earlier studies was 90 minutes, divided into 30 minute intervals of prone positioning, car seat and then prone positioning again. This study, however, evaluated infants for 90 minutes each in crib and car seat, which is a considerably longer observation time in each setting.

Of interest is comment that these authors re-tested 22 of the infants who “failed” their car seat study at discharge and found that 20 “passed” at 40 weeks adjusted age while the remaining 2 “passed” at 44 weeks adjusted age. This would perhaps tend to support Willett’s[23] finding that prematurity is a predictive factor for respiratory compromise in a car seat.

Young *et al* conclude that their observations support the AAP recommendations for evaluation of premature infants in a car seat before discharge. As a result of their observation that infants who had significant desaturation while in a crib usually “failed” the car seat test, they also conclude that a car seat study alone is sufficient to screen at risk infants. There is then the option to further evaluate those infants who fail the car seat test criteria if required. This conclusion appears to relate to concerns about whether or not all infants <37 weeks gestation should undergo a period of monitoring in

a car seat or whether it might be possible to monitor select groups. The consensus seems to be that the AAP policy recommendations are appropriate and all infants <37 weeks should be monitored.

Respiratory Instability of Term and Near-Term Healthy Newborn Infants in Car safety seats. 2001

In an effort to further clarify the findings from previous studies which show that premature and LBW infants are more likely to suffer respiratory compromise in a car restraint, Merchant *et al*[29] studied 50 infants of 35 – 36 weeks gestation and 50 term infants for changes in heart rate, respiratory rate and pulse oximetry whilst supine and whilst in their car seat to try to determine if AAP policy recommendations should apply to all premature infants or just very premature infants. Apneic and bradycardiac events were also recorded.

The rationale for this study was that infants born at 35-36 weeks gestation made up 4 – 6% of all newborns in that population at that time; they were usually healthy and as they did not require special newborn care were usually admitted direct to the newborn nursery. They are at lower risk of apnea of prematurity and unless they are specifically at risk of respiratory instability in a car seat, it would be difficult, time-consuming and expensive to add a routine period of observation in a car seat to a short hospital stay.

All newborns at the St Paul Children's Hospital were eligible for inclusion in the study provided they had never required intensive or convalescent care in the NICU. Enrolment into the study was sequential and efforts were made to ensure that both healthy infants with normal perinatal histories were recruited as well as infants who experienced difficulties during labour or delivery. This latter because transient complications of pregnancy, labour or delivery may have an impact on physiological stability in the immediate newborn period.

Infants were tested on the day of planned discharge or the day before planned discharge depending on parental preference. Infants were observed for heart rate, respiration and pulse oximetry for 30 minutes while in a supine position and then for 90 minutes in a car restraint. Additional padding was used as required for both pre-term and term infants and the placement and number of rolls required for each infant was also recorded.

This study used two monitors to record the values of the variables of interest. One monitor recorded continuously and the other recorded pre-defined events. This

ensured that each infant observed had both a recording for each event experienced as well a continuous recording of oximeter readings. Events were defined as heart rate <80 beats / minute; respiratory pause >20 seconds or oxygen saturation <85%. The event monitor saved the 30 seconds before the event as a baseline and continued for 60 seconds after the event or until the end of the event, whichever was the longer. In order to exclude normal transient alterations in heart rate, respiration and oxygenation, significant events were defined as heart rate <80bmp for >4 seconds with oxygen desaturation <80%; heart rate <80bpm for >10 seconds without oxygen desaturation; apnea >20 seconds with oxygen desaturation <80% or heart rate <80bpm. In addition to these criteria, a study was also considered to be abnormal if SaO_2 saturation values dropped steadily and fell below 85% while the infant was in the car restraint.

The two groups did not differ significantly in their SaO_2 saturation values observed whilst supine and in the car restraint. However, mean oxygen saturation values in both groups declined from 97% in the supine position to 94% after 60 minutes in the car restraint. Oxygen saturation values recorded in the car seat were significantly lower than recordings in the supine position. Seven infants had oxygen saturation values of between 85% - 90% for >20 minutes in their car seats. These seven infants were evenly distributed between the 35 - 36 week infants and the term infants (3 preterm and 4 term). Twelve percent (n=6) of the pre-term infants experienced apneic or bradycardiac episodes in their car seat, while none of the term infants experienced these events. There was no difference observed in the incidence of apnea or bradycardia between the infants born at 35 weeks and those born at 36 weeks gestation.

Responding to concerns that infant car restraints had changed over time from the early studies by Bull *et al* and Willetts *et al* this study also assessed the infant car restraints the parents brought in to determine if they met current standards and whether the infant could be positioned securely in the restraint. Where the restraint provided by the parent met current standards but the infant could not be properly positioned and secured, an alternative car seat with a five point harness was provided through the hospital rental scheme. Restraints provided by the parents were deemed unsuitable if they were:

- a dedicated forward facing restraint
- over six years of age
- purchased second hand with no knowledge of previous crashes or
- a recalled product

Also described were the criteria for proper positioning and fitting of the infant into the restraint.

This study found that 24% (n=12) of pre-term and 4% (n=2) of term newborn infants did not fit securely into their car seat, despite the use of blanket rolls. Both of the term infants who did not fit securely into their car seat had a birth weight of <2500g. Thirteen of the restraints supplied by parents did not meet current standards and 8 parents did not have a restraint at all.

The authors note that the study sample has a higher rate of caesarean section birth than the hospital average and a high number of twins and triplets. The longer hospital stays of these infants facilitated enrolment in the study. What influence or effect the high number of multiple births may have had on the findings of this study is not discussed by the authors.

The primary difference between this study and many of the earlier studies is that the study population were healthy newborns cared for in a normal nursery, rather than newborn infants who required more intensive care and the already noted high number of multiple births in the sample; no other study has reported a high number of multiple births in their sample.

Merchant *et al* conclude that the results of their study affirm the AAP recommendations that all infants born at <37 weeks gestation be evaluated in their car seat for respiratory stability prior to discharge. They also suggest that monitoring apparently healthy infants in their car seat can identify previously undetected conditions such as apnea of prematurity or gastroesophageal reflux.

Their discussion around the issues of positioning and fitment of small babies puts responsibility for fitment resolutions straight back to manufacturers and affirms the recommendation to restrict travel with both premature infants and term infants in the first few months.

In light of the high number of multiple births in their study sample, Merchant *et al* take issue with the AAP recommendation regarding the use of a car bed for premature infants. As this type of restraint takes up more than one seating position, where there is more than one infant or there are other children in the family, this becomes impractical. Instead they suggest that simply reclining the infants own restraint a little more may resolve problems with SaO_2 desaturation.

Simple Insert to Prevent Airway Narrowing in Pre-Term Infants: A Pilot Study. 2003

Following on from the concept of increasing the degree of recline of infant car restraints for premature infants, Tonkin *et al*[30] tested whether a specific design of insert for an infant restraint would maintain the infant's head in a neutral position on the trunk thus preventing narrowing of the airway and subsequent oxygen desaturation in premature infants. The study was undertaken at the National Women's Hospital, Auckland, New Zealand.

A sample of seventeen premature infants approved for hospital discharge were evaluated in an infant restraint with and without a foam insert which had a slot for the back of the infant's head. The infants in the study were born at 32.0 ± 3.5 weeks gestation and weighed 1792 ± 599g at birth. At the time of the study, infants were 38 weeks ± 40 days old and weighed 2472 ± 426g. Ten of the seventeen infants had one or more documented episodes of apnea or bradycardia while in hospital but had no recorded episodes in the week prior to the study.

Each infant in the study was observed for 30 minutes in an infant restraint with the insert in place and then for a further 30 minutes without the insert. The authors note that it would have been preferable to have randomised the order of the study but they found that the infants were consistently aroused by the placement of the insert into the restraint. The insert could however be removed without disturbing the infant, which reduced delays between study periods.

Once in the restraint, radiography of the upper airway was performed in each of the two study periods per infant. Radiography was timed to image the airway during inspiration. Infants were also monitored for heart rate, respiratory rate, nasal air flow and pulse oximetry. Oxygen saturation <85%, bradycardia <90bmp and arousal defined as "the combination of highly variable respiratory recordings with increased heart rate and muscle activity". Obstructive apnea was identified by reduced airflow with increased respiratory effort.

This study found that with the insert in place all infants were able to maintain their head in a neutral position but that when the insert was removed, the majority of infants' heads slumped forward, pressing the chin against the chest.

The majority of infants (n=14) had wider airways with the insert in place. Analysis of the radiographs showed that without the insert, the distance between the upper end of the

nose and the lower jaw reduced from 15.6 ± 3.5mm to 12.5 ± 3.3mm. In addition the angle from the upper jaw to upper end of nose to lower jaw increased, indicating that the jaw was being pushed upward and backward while in the infant restraint without the insert. The insert was also associated with significant reductions in the frequency of SaO_2 desaturation to <85% and bradycardia <90bpm.

Tonkin *et al* conclude that their study demonstrates that narrowing of the upper airway occurs if a premature infant restrained in a car seat slumps their head forward to their chest. This narrowing is associated with higher rates of SaO_2 desaturation and bradycardia and frequent arousals. They suggest that their observations may also support the notion that more frequent arousals may be beneficial for infants responding to life threatening events. Finally they recommend that further studies are needed to evaluate crash safety of the modification and to establish how long premature infants would need to continue to use such an insert.

Discussion

These eleven studies conducted over a 20 year time period all demonstrate physical fitment problems and adverse respiratory outcomes for premature and LBW infants, as well as some term infants, in child car restraints. The majority of the studies have been undertaken in the USA and Canada, with one being undertaken in New Zealand.

They pose a number of questions for Australian health and injury prevention professionals in terms of recommending child car restraints for premature and LBW infants in Australia. As Merchant *et al*[29] identified infant car restraints change over time as manufacturers respond to research findings, changes in regulatory standards and consumer / market demands. Australian infant restraints have always been different from those manufactured for the American, European or other markets.

Currency and description of restraints

A number of the studies described earlier, when referring to the infant car seat used in their study, describe them as being used in their semi-upright position but do not specify what is meant by "semi-upright" position. The specific brands and models used in many of these studies have either ceased being manufactured, changed names as companies have merged or have simply been re-designed over time. Without clear definitions of what is deemed a semi-upright position, it is very hard for health and injury professionals in Australia in 2005 to determine if there is any comparison

possible with currently available Australian Standards infant car restraints, especially as very few of the brands and models identified have ever been available in Australia.

Smith and Turner[24] were the first to quantify and describe the degree of recline on the infant restraints they were using in their study. This study is also the first indication for people unfamiliar with the specific products that these infant restraints have more than one recline position for infants. In studies where the degree of recline has been quantified, there is some variability between them as to how the degree of recline is described. Some studies[24] describe the degree of recline as an obtuse angle (>90°) while others[27] describe it as an acute angle (<90°) although none describe how the angles were measured. While this is not a major problem as the interpretation is that the angle is measured either as the internal angle of the restraint or the external angle created by the back of the restraint and the horizontal plane (Figure 5), it does mean some translation between studies for comparison to be possible.

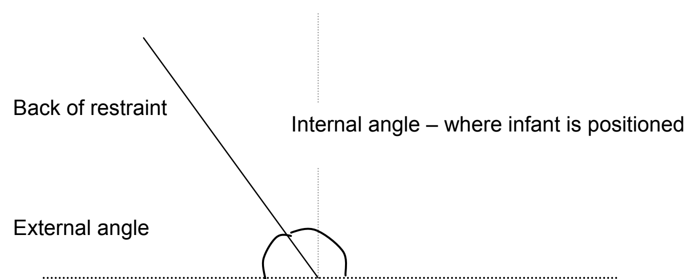

Figure 5: Interpretation of measurement of degree of recline in infant restraints.

While all the authors recommend that infants should be in a rear facing position in the car, it is rarely clearly spelled out that the restraints they have used are intended to be used rear facing for newborns and young infants.

In Australia, prior to the introduction of the Safe-n-Sound infant capsule in the early - mid 1980's, the only dedicated infant restraints for newborn and very young babies were bassinettes or "Swinger" style restraints that were positioned across the back seat of a vehicle, in which the infant lay, either prone or supine. When the Safe-n Sound infant capsule was introduced it was a whole new way for parents to safely transport their infants in a car as it is a dedicated rearward facing infant restraint, utilising a single seating position. Unlike the American infant restraints used in these studies, the Australian infant capsule does not have variable recline positions – it has a single fixed recline position for the infant. The only further influence on the degree of recline for the infant is the slope of the vehicle seat where the capsule is fitted; a flatter vehicle seat

means the degree of recline remains close to design but a highly sloped vehicle seat makes the degree of recline more upright. Hamelin *et al*[27] demonstrated in their study how this effect can be minimised with the placement of a firm padding under the restraint to adjust for the slope of the vehicle seat. Even as other styles of dedicated infant restraint and convertible restraints appeared on the Australian market over time, they all had, and still have, only a single recline position for newborn and young infants who travel in a rearward facing position.

The questions then for Australian health and injury prevention professionals are:

- Do the findings of these studies have relevance for infant car restraints designed and tested against the Australian Standard for child car restraints?
- Does the angle of recline on Australian Standard infant car restraints provide a recline position suitable to reduce the potential for oxygen desaturation, apnea or bradycardia in premature and LBW infants?
- Child car restraint designs have changed over time; are the physical fitment issues identified in these studies still relevant with regard to current models?

Definitions and significance of events of interest

Each of the previously described studies demonstrated that premature, LBW and some term infants have episodes of apnea, bradycardia and / or oxygen desaturation whilst in infant car restraints yet there is little clarity regarding what is considered to be a normal range of values or what the consequences of these conditions are for premature or term infants.

The criteria for defining events of interest or significance in the studies reviewed designate values between 85% - 90% for oxygen saturation; values of <80 beats per minute for bradycardia and apnea at >20 seconds, with some variation according to the combination of events to define a severe event within particular studies. A study by Poets *et al*[31] reported a median baseline SaO_2 of 99.4% (range of 88.9 – 100%) in 66 premature infants ready for discharge from the special care nursery, monitored for arterial oxygen saturation, breathing movements and airflow. All except one of these infants had falls in SaO_2 to ≤80% which were more frequent and of longer duration than seen in full term infants. They observed that the frequency of relatively prolonged episodes of desaturation (SaO_2 ≤80%) decreased significantly with increasing gestational age. Bass[35] also cites another study by Poets in which it was shown that the baseline saturation of term and preterm neonates ranges between 93% - 100% and

between 97% - 100% in term and preterm infants. Periods of oxygen desaturation and periodic breathing in both term and premature infants appear to be common.

According to Martin et al[32], the relationship between apnea, bradycardia and desaturation is complex. Apnea is often the initiating event causing a fall in oxygen saturation, which then triggers bradycardia but desaturation may occur as a primary event, also triggering bradycardia. According to Martin *et al* there is no relationship shown between persistent apnea or bradycardia and sudden infant death syndrome, nor is there evidence that prolonged apnea is associated with intracranial abnormalties[33]. Only one study reports the death of a premature infant in a car restraint on the way home[25]. In Australia, the only identified death of a child in a child car restraint that was not crash related occurred in South Australia, where a 16 month old left asleep and unsupervised in his car seat, strangled on the harness straps[34].

Bass[35] cites published reports that show cognitive and behavioural difficulties in infants who are exposed to chronic or recurrent hypoxia, which is countered in a reply by Stening[35] citing a study which showed oxygen saturation level as having little influence on neurological outcome or retinopathy and no correlation to the development of cerebral palsy.

For some of the infants in these studies, episodes of oxygen desaturation and bradycardia self-resolved, while for others the study was terminated with the infant being removed from the restraint in order to resolve the conditions. Tonkin *et al*[30] suggest that the arousal they observed in premature infants in car restraints may be a mechanism for the infant to self resolve conditions that are a threat. In contrast, Dimaguila *et al*[36] suggest that hypoxemic episodes in LBW infants on ventilatory support are triggered by spontaneous movement during sleep.

Given that the question of long term consequences of apnea, bradycardia and oxygen desaturation may remain unresolved, are there perhaps differences between premature or LBW infants in Australia now and the infants in these studies? Are there differences in treatment and care that might reduce the risk of respiratory compromise for premature infants in Australia?

Policy

Several of the studies reviewed contributed to the development of both the American Academy of Pediatrics Policy on the safe transport of premature and low birth weight infants and the Canadian Paediatric Society’s Position Statement on the assessment of

premature infants for car seat safety before discharge. A number of other studies have attempted to determine whether or not the AAP recommendation to monitor all infants born at <37 weeks gestation in their car seat is warranted, while others have described their experiences in implementing the AAP Policy recommendations. All have concluded that in spite of their own initial premises, their study findings confirmed that infants born <37 weeks experience episodes of apnea, bradycardia or oxygen desaturation in an infant car restraint and should therefore be monitored prior to discharge.

There appears to be no similar policy or position statement by the Royal Australasian College of Physicians; Paediatric and Child Health Division. Do Australian Neonatal Intensive Care Units have a policy of monitoring premature infants in car restraints prior to discharge? Is this apparent lack of policy because there is no evidence of similar issues in Australia or because the issue has already been resolved in a study that has not been detected by the search strategy of this paper or for other reasons?

McMillan[37] cites infants born at <37weeks gestation as making up 6% of infants born in Canada and asks how the AAP recommendations might best be implemented for this proportion of infants, given that Young *et al*[28] identified that 19 out of 22 Canadian NICUs discharged premature infants without first monitoring them in their car seat.

In Australia, in 2001, 7.8% of all births were preterm (<37 weeks gestation) with most of the preterm births at 32–36 weeks. Just over six percent (6.2%; n=15,751) of live born infants were classified as Low Birth Weight (<2500g). Indigenous infants are almost twice as likely to be low birth weight as non-indigenous infants. Twins are more likely to be born preterm and to be low birth weight than singleton babies. Babies born as a result of assisted reproductive technology (ART) also are more likely to be preterm and to have a lower average birth weight compared with all Australian babies. Nationally, 0.8% of births were at 20–27 weeks gestation, 0.8% were at 28–31 weeks, and 6.1% were at 32–36 weeks gestation.

Of the 5,241 babies admitted to Level III Neonatal Intensive Care Units in Australia in 2001, 50.0% had a gestational age of less than 32 weeks and 42.6% had a birth weight of less than 1,500 grams.

For Western Australia in 2002, 8.1% (n=2,102) of the total births were <37 weeks gestation. Of the 1,499 singleton births, 6.3% were preterm and of the 773 multiple births, 57.6% were preterm.

Nationally and within Western Australia, with approximately 8% of births being preterm, it would seem advisable to have some knowledge of whether or not these 8% of infants are being discharged from the hospital to be placed at risk of oxygen desaturation in their car restraint, without parents being aware of the potential risk. The existing evidence would suggest that Australian premature infants are being placed at risk in this manner, but as already suggested these studies are in the main ten to fifteen years old; use restraints that are 1) different from those available in Australia or 2) that are now superseded.

As a result of this review of recommendations and information for the transport of premature infants the following recommendations are made.

Recommendations

1. Australian research is required to determine if the existing recommendations for the transport of premature infants have relevancy in Australia with recent model Australian Standards infant car restraints.

2. Australian Standards restraints should be evaluated for their suitability for use by premature and low birth weight infants in order to be able to recommend suitable restraints for parents.

3. The Australian Standard for child car restraint systems should consider introducing a lower weight specification in testing programs to ensure that the 8% of infants who are born preterm or are LBW have the same access to safe transport systems as other infants.

4. In order to carry out a lower weight specification testing program, a test dummy weighing approximately 2kgs and being of a similar size as a premature infant should be developed.

5. A review of current recommendation, information, practice and policy regarding the transport of premature infants at discharge should be conducted with Australian Neonatal Care Unit’s and with the Royal Australasian College of Physicians.

6. Parents of all infants, premature or term, be left in no doubt that child car restraints are highly effective in preventing death and injury in car crashes and that in no circumstances should they consider not using a child car restraint.

7. Parents of all infants, premature or term be educated in how to properly position and fit their infants in their car restraint and how to properly use their child car restraint by health and injury prevention professionals knowledgeable about child car restraints.

Further Research

The objectives for further research in recommendations one and two should be:

1. To determine if infants born at <37 weeks gestation are likely to experience oxygen desaturation, apnea or bradycardia whilst in an Australian Standards infant car restraint.
2. To assess physical fitment of infants born at <37 weeks gestation or less than 2kg in weight, but ready for hospital discharge in current model Australian Standards child car restraints.
3. To identify specific Australian Standard infant restraints that are most suitable for premature or LBW infants in terms of fit and reduced risk of respiratory compromise.

Methodological Issues

Some of the methodological issues that need to be considered for future research are:

Ethics and Consent:

Ethics approval and parental consent will be essential for research of this nature to proceed. Both Ethics Committees and parents will need to be convinced that infants will not be harmed or compromised by participating in the research, so very clear termination guidelines will need to be developed in consultation with medical and nursing staff and from any existing evidence showing that infants will not be at risk.

The support of medical and nursing staff at hospitals likely to be involved in the research will need to be obtained. Usually, this would involve a process of meetings with and presentations to relevant personnel within the hospital staff to explain the proposed research, its benefits and potential outcomes.

Study Population

The population from which the sample for future research could be selected should be infants who were born at <37 weeks gestation or weighing <2 kg and are now within one week of discharge and not requiring additional oxygen.

Recruitment of the sample should be through Level III and Level II Neonatal Intensive Care Units. It is suggested that if possible, more than one hospital be used, provided treatment and care regimes are similar.

The assistance of a biostatistician should be sought to determine the appropriate sample size to detect effects with some significance.

Consideration should also be given to recruiting some term infants in future research as a comparison group.

Materials and equipment

A range of dedicated and convertible infant restraints should be used. Measurement of the distances between seat back and crotch strap and seat bottom and lowest harness level should be recorded for comparison with the measurements recommended in the AAP Policy. Clear definitions of the criteria for assessing the fit of the harnessing on the infant will be required. Consideration needs to be given to how to determine what a representative sample of restraints might be so that the research does not become too long a process for each infant enrolled in the study.

The degree of recline of the restraint on a flat surface should be documented as well as the degree of slope of the vehicle seat where the parent intends to place their infant restraint. During the observation period in the infant restraint, restraints should be positioned at the same angle as it would be in the parent's car.

The studies reviewed provided detailed information on the equipment they used to measure physiological variables. Medical and nursing advice will be required to determine what equipment is appropriate for measuring the clinical variables of interest and to aid with interpretation of recordings.

Variables of interest

The physiological variables of interest will be oxygen saturation levels, bradycardia and apnea. On the basis of existing studies, the criteria for significant events are likely to be oxygen saturation < 85% or 90%; bradycardia at <80bpm and apnea >20 seconds. These criteria will need to be assessed against current practice and guidelines.

Each observation period for each infant should be videoed so that a visual record of each observation is kept.

Methods

Infants should be monitored for oxygen saturation levels, bradycardia and apnea whilst in their crib, in an infant restraint and then again in their crib.

Based on previous studies and taking into account potentially longer travelling times in Australia, it is suggested that the monitoring period be 2 hours duration, divided into 30 minutes in crib, 60 minutes in infant restraint and 30 minutes in crib.

Infants should be randomly assigned to a different restraint at each observation period, which should occur on sequential days, until they have been monitored in each of the restraints being used for the study.

Analysis

The assistance of a biostatistician should be sought in determining the most appropriate statistical methods to analyse the data collected. The research will be looking for within group differences as well as between group differences, so ANOVA and χ^2 analyses are likely to be appropriate statistical methods.

Consultation

Further research will require consultation with:

- neonatal experts
- medical and nursing staff
- parents
- biostatistician
- child restraint fitting experts

Outcomes

At the conclusion of the observations, parents will be given information on how best to fit their car restraint into their vehicle and how best to fit their infant into the restraint to ensure benefit.

The outcomes of this proposed further research should also lead to the development of evidence based policy and practice for Australian Neonatal Intensive Care Units with regard to the transport of premature infants at discharge.

Statement of Participation

The work to search, review and write this project has been my own.

Some assistance was provided by Judy Hartigan, the librarian at the Injury Research Centre who passed on papers she thought might be of interest and value to my topic of interest.

Tiffany Foreman and Arlette Cohen, from the Neonatal Unit at King Edward Memorial Hospital for Women were also of assistance in describing to me some of the practices and procedures in the neonatal unit our major tertiary hospital in Western Australia.

Mike Lumley, Business Manager, Technical Quality and Shane Sheely, State Sales Manager WA, NT and SA for Britax Child Care Products have made themselves available to answer questions related to infant car restraints in Australia where required.

Glossary

Apnea

Apnea, defined as "an absence of spontaneous respiration"[19], is a common condition in premature infants that often requires cardiopulmonary monitoring and results in a prolonged hospital stay. A standard clinical definition of apnea is cessation of inspiratory gas flow for 20 seconds, or for a shorter period of time if accompanied by bradycardia (heart rate less than 100 beats per minute), cyanosis, or pallor. A number of different types of apnea are described[20]:

Central apnea: *occurs when the brain fails to send the appropriate signals to the breathing muscles to initiate respirations.*

Obstructive apnea: *occurs when there is inspiratory effort without airflow; ie the airway is obstructed.*

Mixed apnea: *is when both central and obstructive apnea occur in the same episode*

Periodic apnea: *a normal condition in the full-term newborn characterised by an irregular pattern of rapid breathing followed by a brief period of apnea, usually associated with rapid eye movement sleep.*

Apnea of Prematurity: *is a specific diagnosis. The condition usually resolves between 34 to 36 weeks post-conceptual age.*

Bradycardia

A condition in which the ventricles beat but at less than 60 beats / minute

Cyanosis

Bluish discoloration of the skin and mucous membranes caused by a lack of oxygen in the blood. Cyanosis is associated with cold temperatures, heart failure, lung diseases, and smothering. It is seen in infants at birth as a result of heart defects, respiratory distress syndrome, or lung and breathing problems

Hypoxemia

An abnormal deficiency of oxygen in the arterial blood

Hypoxia

Inadequate oxygen at the cellular level, characterised by tachycardia, hypertension, peripheral vasoconstriction, dizziness and mental confusion

In severe hypoxia, the central mechanisms that regulate breathing fail, leading to irregular respiration, apnea and respiratory and cardiac failure. The tissues most sensitive to hypoxia are the brain, heart, pulmonary vessels and liver.

Neonatal

The period of time covering the first 28 days after birth

Neonatal Care Levels

Level I care is for normal healthy term babies, some of whom may need short-term observation during the first few hours of life.

Level II refers to a nursery that generally has babies born at 32 to 36 weeks gestation weighing around 1,500 to 2,500 grams at birth. It includes care for babies who require intravenous therapy or antibiotics, and/or those who are convalescing after intensive care, and/or those who need their heart rate or breathing monitored, and/or those who need short-term oxygen therapy.

Level III or intensive care refers to the care of newborn infants who require more specialized care and treatment. It includes most babies born at less than 32 weeks gestation or less than 1,500 grams birth weight, and others who may require intravenous feeding, and/or surgery, and/or cardio-respiratory monitoring for management of apnea or seizures, and/or require assisted ventilation, and/or supplemental oxygen over 40% or long-term oxygen[6].

Oxygen Saturation

The fraction of a total haemoglobin in the form of SaO_2 at a defined PO_2. [19]

The extent to which hemoglobin is saturated with oxygen; normal oxygen saturation is 95-100 % if the blood is leaving the heart to the body and 75 % if the blood is returning to the heart after delivering oxygen to the body. If the blood leaving the heart to the body is less saturated than normal, it is called oxygen desaturation.[39]

Premature infant

Any neonate, regardless of birth weight, born before 37 weeks of gestation

Gestational age is often difficult to determine, therefore low birth weight is often a criterion for identifying the high risk infant with incomplete organ system development.

Of primary concern is the stabilisation of and maintenance of body temperature, maintenance of respiration, prevention of infection, provision of adequate nutrition and hydration and conservation of energy.

Preterm
See Premature infant

Prone
Lying face downward

Pulse
Average pulse rate for newborns is 120 beats / minute.

Supine
Lying on the back

Tachycardia
A condition in which the myocardium contracts at a rate greater than 100 beats / minute

References

1. Henderson M. 1994. **Children in Car Crashes; An in-depth study of car crashes in which child occupants were injured.** June 1994. Child Accident Prevention Foundation of Australia, New South Wales Division. Sponsored by the Motor Accidents Authority New South Wales

2. American Academy of Pediatrics; Committee on Injury and Poison Prevention and Committee on Fetus and Newborn. 1996. **Safe transportation of premature and low birth weight infants.** Pediatrics 1996; 97:758-60.

3. Bull MJ, Stroup KB. **Premature infants in car seats**. Pediatrics 1985; 75:336-9.

4. Gee V and Green TJ. (2004). **Perinatal Statistics in Western Australia, 2002**. Twentieth Annual Report of the Western Australian Midwives' Notification System. Department of Health. Perth, Western Australia.

5. Britax Child Care Pty Ltd Australia. Personal communication. 2002

6. Laws PJ & Sullivan EA 2004. **Australia's mothers and babies 2001**. AIHW Cat. No. PER 25. Sydney: AIHW National Perinatal Statistics Unit (Perinatal Statistics Series No. 13)

7. Weber K. **Crash Protection for Child Passengers: A Review of Best Practice**. UMTRI Research Review, July – September 2000. Vol 31:3.

8. Child Accident Prevention Foundation of Australia (Kidsafe) ACT. 1997. ACT Child Restraint Checking: Report of Findings. Kidsafe: The magazine of the Child Accident Prevention Foundation of Australia: Spring 1997. Ed Carol Taylor

9. Kidsafe WA. 1998. **Misuse of Child Car Restraints in Perth WA**. Kidsafe WA

10. Decina LE and Lococo KH. 2003. **Misuse of Child Restraints DOT HS 809 671** May 2003 Office of Research and Technology, National Highway Traffic Safety Administration, Washington, DC

11. Graham CJ, Kiltredge D, Stuemky JH. **Injuries associated with child seat safety misuse** Pediatric Emergency Care 1992; 8:351-3.

12. **Road Traffic Code 2000**, Government of Western Australia, 2004

13. Standards Australia. **Child restraint systems for use in motor vehicles**. AS/NZS:1754:2004

14. Britax Child-Care Products Pty Ltd. 2002. **Safe-n-Sound Child restraint Education Course**. Britax Child-Care Products Pty Ltd. 2002

15. Kidsafe WA. 1999. **Child Restraint Education Course**. PowerPoint presentation. Kidsafe WA May 1999

16. American Academy of Pediatrics Committee on Injury and Poison Prevention and Committee on Fetus and Newborn, **Safe transportation of premature infants**. Pediatrics 1991; 87:120-2.

17. Canadian Paediatric Society; Fetus and Newborn Committee. **Assessment of babies for car seat safety before hospital discharge** http://www.cps.ca/english/statements/FN/fn00-02.htm (Harriet Lane Links) Paediatrics 04-12-2000

18. American Academy of Pediatrics; Committee on Fetus and Newborn **Hospital Discharge of the High-Risk Neonate – Proposed Guidelines.** Pediatrics. 1998. Vol 102, No 2; pp 411 – 417

19. Mosby's Medical. Nursing & Allied Health Dictionary. 5th Edition. 1998.

20. http://neonatal.peds.washington.edu/NICU-WEB/apnea.stm

21. Bull MJ, Weber K, Stroup KB. **Automotive restraint systems for premature infants.** Journal of Pediatrics 1988; 112: 385 – 88

22. Willett LD, Leuschen MP, Nelson LS, Nelson RM Jr. **Risk of hypoventilation in premature infants in car seats.** Journal of Pediatrics 1986; 109:245-8.

23. Willett LD, Leuschen MP, Nelson LS, Nelson RM Jr. **Ventilatory changes in convalescent infants positioned in car seats.** Journal of Pediatrics 1989;115:451-5

24. Smith PS, Turner BS. **The physiologic effects of positioning premature infants in car seats.** Neonatal Network 1990; 9:11-5.

25. Bass JL, Mehta KA, Camara J. **Monitoring premature infants in car seats: Implementing the American Academy of Pediatrics policy in a community hospital**. Pediatrics 1993; 91:1137-41.

26. Bass JL, Mehta KA. **Oxygen desaturation of selected term infants in car seats.** Pediatrics 1995;96:288-90

27. Hamelin K, Overly B. **Premature infants and car seat safety.** The Canadian Nurse 1996; 92(4):31-4.

28. Young B, Shapira S, Finer NN. **Predischarge car seat safety study for premature infants.** Paediatric Child Health 1996; 1:202-5.

29. Merchant JR, Worwa C, Porter S, Coleman JM, deRegnier RO **Respiratory Instability of Term and Near-Term Healthy Newborn Infants in Car safety Seats.** Pediatrics 2001; 108, No 3 pp647 -52

30. Tonkin SL, McIntosh CG, Hadden W, Dakin C, Rowley S Gunn AJ. **Simple Insert to Prevent Airway Narrowing in Pre-Term Infants: A Pilot Study.** Pediatrics 2003; 112 (4): 907 – 13

31. Poets CF, Stebbens VA, Alexander JR, Arrowsmith WA, Slafield SAW, Southall DP. **Oxygen saturation and breathing patterns in infancy. II. Preterm infants at discharge from special care.** Archives of Diseases of Childhood 1991; 166: 574 - 8

32. Martin RJ, Fanaroff AA. **Neonatal apnea, bradycardia, or desaturation: Does it matter?** Journal of Pediatrics 1998; 132:758-9.

33. Eichenwald EC, Aina A, Stark AR. **Apnea frequently persists beyond term gestation in infants delivered at 24 to 28 weeks.** Pediatrics 1997; 100:354-9

34. Byard RW, Beal S, Bourne AJ. **Potentially dangerous sleeping environments and accidental asphyxia in infancy and early childhood.** Archives of Disease in Childhood P 618.9205 P5 1994;71:497-500

35. Bass JL, Stening W, Nitsch p, Roth B. O_2 **Saturation and Slings.** Letters to the Editor. Pediatrics 2004:113; 169-170

36. Dimaguila MAVT, DiFore JM, Martin RJ, Miller MJ. **Characteristics of hypoxemic episodes in very low birth weight infants on ventilatory support.** Journal of Pediatrics 1996; 130: 577- 83

37. McMillan DD. **How should premature infants be assessed for car seat safety before discharge?** Paediatric Child Health 1996; 1:197-9.

38. Stein N **Car-Seat Test** Pediatrics 2004; 113 (5) 1469

39. staff.aub.edu.lb/~webchc/glossary11.htm