Minimizing the Risks of Sudden Infant Death Syndrome: To Swaddle or Not to Swaddle?

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Objective To evaluate the effects of swaddling on infant arousability, particularly the progression of subcortical activation (SCA) to full cortical arousal (CA), because impaired arousal may contribute to sudden infant death syndrome.

Study design Healthy term infants, who were routinely swaddled (n = 15) or unswaddled (n = 12) at home, were studied with daytime polysomnography at 3 to 4 weeks and 3 months after birth. When both swaddled and unswaddled, arousability was assessed with a pulsatile jet of air at the nostrils.

Results Larger increases in overall arousal thresholds (SCA plus CA) with swaddling were observed in infants who were easiest to arouse when unswaddled. Swaddling did not alter SCA or CA frequencies of routinely swaddled infants at either age. In infants who were naïve to swaddling, arousal thresholds were increased and CA frequency decreased during swaddled quiet sleep at 3 months.

Conclusions This study provides a scientific basis for assessing the safety of swaddling in infant care practice. The decreased cortical arousals observed in infants unfamiliar with swaddling may correspond to the increased risk of sudden infant death syndrome for inexperienced prone sleepers. *(J Pediatr 2009;155:475-81)*.

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Sudden infant death syndrome (SIDS) is one of the leading causes of infant death in western countries.[1] Epidemiologic studies identified prone sleeping as the major risk factor for SIDS.[2] In the 1990s worldwide public awareness campaigns began promoting supine sleeping to prevent SIDS. As a direct result, SIDS rates were reduced by more than 50% in most western countries.[2,3] However, the fall in the prevalence of prone sleeping has since plateaued, and many parents have become noncompliant with safe sleeping guidelines. Despite the well-documented risks of prone sleeping,[4,5] in some areas up to an alarming 25% to 30% of parents/caregivers continue to place their infants in this position to sleep.[6-8] Most of these caregivers report their babies "are more comfortable" or "sleep better that way," and some also describe excessive crying of babies in the supine position. As an alternative to prone sleeping, swaddling, or tight wrapping of infants has been recommended by some Australian SIDS organizations as a method of settling infants in the supine position. The popularity of infant swaddling has also recently increased in the United States.[9]

The final event leading to SIDS may involve an inability to arouse from sleep in response to a respiratory or cardiovascular challenge.[10,11] The arousal hypothesis is supported by postmortem identification of dysfunction in brain regions relevant to cardiorespiratory control and arousal from sleep in SIDS victims.[12] Furthermore, previous studies have reported decreased total arousability to various stimuli and altered brainstem-cortex arousal patterns in infants sleeping in the prone position, the major risk factor for SIDS.[13-15]

Infant swaddling minimizes arousals from sleep, crying time, spontaneous startles, and the progression to full arousal.[16-18] In contrast, other studies have reported that infants are more sensitive to auditory challenges in active sleep (AS) when swaddled.[19] During quiet sleep (QS), a state where infant arousability is already reduced,[20] potential effects of swaddling on induced arousability are unknown. Furthermore, although the most recent definitions for infant arousal responses recognize that the process of arousal represents a progression from subcortical activation (SCA) to full cortical arousal (CA),[21] the consequences of swaddling on this progression remain unstudied.

ANOVA	Analysis of variance
AS	Active sleep
CA	Cortical arousal
EEG	Electroencephalography
NS	Not significant
RM ANOVA	Repeated measures analysis of variance
SCA	Subcortical activation
SIDS	Sudden infant death syndrome
QS	Quiet Sleep

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Before widespread promotion of swaddling as a safe settling method, a fuller understanding of the effects of swaddling on infant arousability is needed. Thus the aim of this study was to evaluate the effects of swaddling on stimulus-induced arousal pathways during both AS and QS, both in infants who were routinely swaddled and those who were unswaddled at home. We hypothesized that swaddling would suppress infant arousability to somatosensory stimulation by minimizing the progression to full CA.

Methods

Twenty-seven healthy infants (17F/10M) were studied. All infants were born at term (range 38 to 41 weeks of gestation) and were of normal birth weight (mean ± SEM, 3462 ± 85 g) and 5-minute Apgar scores (median 9, range 9-10). None of the mothers smoked during pregnancy. The infants were all breast fed and routinely placed in the supine position to sleep at home.

Ethical approval for this project was obtained from the Southern Health and Monash University Human Research Ethics Committees. Participation was entirely voluntary, with no monetary incentive provided. Written informed parental consent was obtained before study commencement.

Polysomnography

Daytime polysomnography was performed at both 3 to 4 weeks (n = 27) and 3 months (n = 26) postnatal age, in a sleep laboratory where the ambient temperature was 23.0° ± 0.1°C and noise was minimal. A 16-channel polygraph (Model 78A; Grass Instrument Co., Quincy, Massachusetts), running at a sampling rate of 500 Hz, recorded electroencephalography (EEG), left and right electrooculography, mental-submental electromyography, electrocardiography, abdominal skin temperature (YSI 400 Series Thermistor; Mallinckrodt, Melbourne, Australia), thoracic and abdominal breathing movements (Piezo-electric sensors, Resp-ez; EPM Systems, Midlothian, Virginia), nasal/mouth airflow (BreathSensor thermistor; Nellcor Puritan Bennett Ltd, Eden Prairie, Minnesota), expired CO_2 (Capnocheck Plus; SIMS BCI Inc, Waukesha, Wisconsin), and blood oxygen saturation (BIOX 3700e pulse oximeter; Ohmeda, Louisville, Colorado). Electrodes and leads were attached during the routine morning feed, and the study began when the infant was asleep in the supine position in a bassinet.

Study Protocol

At each age, infants were studied both unswaddled and swaddled, with the starting condition randomized for the first study and reversed for the next. Infants were swaddled by a single investigator in a light muslin (cotton) wrap with their arms folded across the chest. With the wrap at clavicle level, it was firmly crossed over from side to side, with the larger edge tucked under the infant's back; the excess material was twisted at the feet, loose enough to allow a degree of hip flexion and abduction, then folded beneath the infant. Infants were then covered with a cotton baby blanket. When unswaddled, infants were covered with the same muslin wrap and blanket, but the covering was not wrapped tightly, and the limbs and torso were left unconstrained.

Sleep state was defined as AS, QS or indeterminate sleep, with standard criteria.[22] During both AS and quiet sleep, infant arousability was assessed with a pulsatile air-jet (3 Hz, for 5 seconds) delivered to the left and right nostrils alternately, as described in detail previously.[23] For each stimulus, baseline physiological measurements were obtained from the preceding 10 seconds, and responses were scored as nonarousal, subcortical activation (SCA), or cortical arousal (CA), with standard definitions.[21] This air-jet protocol produced similar arousal responses to those induced by mild hypoxia (15% inspired O_2) challenges throughout the first 6 months of life, both for total arousability[23] and also SCA/CA frequencies.[24]

Data Analysis

Mean arousal thresholds were determined with SCA criteria, so that CA was also captured by the arousal definition, making the arousal threshold inclusive of both SCA and CA. Regression analysis for percent change in arousal threshold between unswaddled and swaddled conditions was performed for each sleep state at each age studied, and the identity and slope of trend lines were compared between sleep states.[25] Non-arousal, SCA, and CA responses were expressed as percentages of total stimuli performed. Two-way repeated measures analysis of variance (RM ANOVA) was used to contrast effects of sleep state and swaddling on arousal thresholds and the frequency of each arousal response (SCA and CA). Two-way RM ANOVA was also used to test for effects on baseline physiological variables (10 seconds pre-stimulus; heart rate, respiratory rate, oxygen saturation, and abdominal skin temperature). Arousal data were also compared between infants who were routinely swaddled at home and those who were not using 2-way RM ANOVA (1 factor repetition) with Student Newman-Keuls post-hoc analysis to identify the source of differences detected by ANOVA.

Results

Overall Group

Effects of Swaddling on Overall Arousal Threshold.

Swaddling had no significant effect on arousal thresholds during AS or QS at 3 to 4 weeks (Figure 1, A). There was an overall effect of swaddling at 3 months, when infants were more difficult to arouse when swaddled ($P < .05$), although after post-hoc analysis this was significant only during QS ($P < .001$, Figure 1, B). At both ages, regardless of swaddling, arousal thresholds were higher during QS than AS ($P < .05$). A negative correlation was observed between the baseline (unswaddled) threshold and the change in threshold when infants were swaddled. This linear relationship was significant ($P < .05$) for both sleep states at 3 to 4 weeks (Figure 1, C) and at 3 months (Figure 1, D) when the slope in AS was greater ($P < .05$).