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The Effects of Anesthesia on the Pediatric Developing Brain: Strategies to Reduce Anesthesia Use in Pediatric MRI and Nursing's Role in Driving Patient Safety

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Purpose: *To describe the physiological and biological principles of anesthesia for children; nonanesthesia practices; the state of the evidence of patient- and family-centered care strategies to reduce anesthesia use; and role of nursing in ensuring patient safety through reducing anesthesia use for pediatric magnetic resonance imaging (MRI).*
Design: *Integrative literature review.*
Methods: *Review and synthesis of experimental and nonexperimental literature.*
Findings: *Anesthesia use in pediatric MRI: 20 studies met inclusion criteria. Physiological and biological side effects of anesthesia in children are substantial. Of significance is the developing research on the extent to which anesthesia affects the developing brain of children. Nonanesthesia in pediatric MRI: 16 studies met inclusion criteria. Common themes were noted between patient- and family-centered care strategies and reducing anesthesia use in children requiring MRI.*
Conclusions: *There are significant risks associated with anesthesia on the developing brain. Nurses play an important role in using patient-centered strategies to reduce pediatric anesthesia use and advocate for patient safety.*

Keywords: *pediatric anesthesia, patient- and family-centered care, nonanesthesia MRI, developing brain.*

IN 2015, NATIONAL statistics indicated that there were 73.6 million children in the United States, and a total of 9.6 million of those children aged between 5 to 17 years were reported to have activity limitations related to one or more health conditions.[1] Furthermore, the population of children in the United States is projected to increase by an additional 1.4 million by 2025.[1] With 13% of

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children in the United States having activity limitations related to one or more health conditions, the likelihood of these children requiring health services is projected to increase to over 10.8 million children per year by 2025. This increase has the potential to place tremendous financial burden on health care and creates access challenges for an already struggling health care system.

With technology advancement and projected increases in health care utilization among US children, the probability of children needing diagnostic imaging is, likewise, expected to increase. In addition, as diagnostic imaging technology has advanced for more than the past 15 years, there is an appreciable growth in the use of magnetic resonance imaging (MRI) as a diagnostic modality for children.[2-4]

There are benefits for the use of MRI as an alternative diagnostic tool, with the most significant benefit noted as reduction in exposure to radiation. However, the length of time needed to complete an MRI study requires the child to remain still for a prolonged period of time; therefore, sedation or general anesthesia (sedation or GA) is typically used. Rates of sedation or GA use for children requiring MRI in the United States are rising at an estimated 7% to 8% per year, exposing an increasing number of children to sedation or GA associated risks and side effects.[4]

A synthesis of the literature related to anesthesia use in MRI indicates that there are several reasons why children are sedated for MRI. The primary rationale for sedation in MRI is to ensure that the child remains still for a prolonged period of time while the MRI is being conducted.[5-8] However, for the pediatric patient, there are many additional factors that can negatively affect the quality of the magnetic resonance image and that are believed to be mitigated through the use of sedation or GA. These include the cognitive and developmental abilities of the child to remain still for prolonged periods of time and to follow directions (eg, to hold one's breath) required for certain MRIs. In addition, feelings of distress or anxiety related to the procedure, fear of the unknown, or fears related to past experiences also limit the child's ability to successfully complete an MRI without sedation, as such sedation may be used.[6] Because of these common biological and physiological challenges faced by children, anesthesia is used when MRI is required. However, there are real and potential physiological and biological risks and side effects of the sedation and anesthetic agents used in anesthesia for children.

Review Method

Identification of Studies and Study Selection

A search of the scientific literature was conducted using research databases such as CINAHL, Academic Search Premier, PubMed, PsychINFO, AMED, the Cochrane Library, Ovid, and MEDLINE to ensure that all the literature pertaining to the fields of pediatric sedation and physiological implications and child life was included in the review. All reviews included the peer-reviewed literature from January 2005 through June 2015, and abstracts were reviewed to determine eligibility for inclusion. Studies were eligible if they were (1) published in English and (2) explored sedation or GA practices in pediatric MRI and nonsedation or non-GA practices in pediatric MRI in the pediatric setting. Studies were excluded if they were not published in English or were not theoretically or empirically based.

All reviews used the following search terms "infant," "child," "pediatric," "adolescent," "juvenile," "teenager," and "youth" to ensure literature pertaining only to pediatrics was included in the review. Sedation or GA in pediatric MRI search terms also included "anesthesia," "analgesia," "sedation," "brain," "pediatric brain," "brain and growth and development," "developing brain," "magnetic resonance imaging," and "MRI" and resulted in 20 studies. Nonanesthesia in pediatric MRI search terms also included "non-anesthesia," "non-analgesia," "non-sedation," "magnetic resonance imaging," and "MRI" and resulted in 16 studies.

Data Extraction and Analysis

Quantitative data were extracted and categorized by the following: author(s), title, journal, year, study purpose, independent variable, dependent variable, number of subjects, subject characteristics, sample design, source or instrument, year data collected, theoretical framework, and study results. The data were then evaluated for commonality in themes and definitions, outcomes measured, and strength of relationships. Findings were then summarized.

Potential Bias and Limitations of Review

To control for biases, the initial search was broad to include all published studies and then narrowed to the focus of this review. Intrinsic in this review are biases based on the choice to include only English language studies. Only electronic databases were used for this search; therefore, the exclusion of research outside the boundaries of the electronic search method might present some bias. Citations of included studies were examined for appropriateness of inclusion.

Findings: State of the Current Evidence

Risks and Side Effects of Anesthetic Agents Used for Children in MRI

The literature presented the efficacy, risks, and side effects associated with the pharmacologic agents used to sedate or anesthetize children needing an MRI. Common drugs used for MRI sedation include chloral hydrate, dexmedetomidine, midazolam-pentobarbital-fentanyl combination, isoflurane, sevoflurane, nitrous oxide, and propofol.[9-14] Incident of side effects from the drugs used for sedation or anesthesia in children for MRI range in occurrence. Potential side effects include emergence delirium (ED), respiratory depression, oxygenation, nausea, vomiting, agitation, and cardiovascular bradycardia.[8,9,14,15] Many researchers explored the effects of drugs used in sedation or anesthesia to understand the best combinations of drugs to minimize side effects and the best type of drug to use based on the patient's physiological challenges. For the purposes of this review, a synthesis of the literature was delineated into three categories: ED, recovery (awakening) time, and the effects of sedation or GA on the developing brain.

EMERGENCE DELIRIUM. ED is a troubling side effect of sedation or GA in children. It is described as "a mental disturbance during the recovery from general anesthesia consisting of hallucinations, delusions and confusion manifested by moaning, restlessness, involuntary physical activity and thrashing about in bed."[16 p 16] The incidence of ED in children ranges from 18% to 80%, and the reason for this phenomenon is still being explored. However, it is thought to be a direct result of the time it takes the child to awaken from anesthesia.[9,17] In 2004, Sikich and Lerman[18] developed the Pediatric Anesthesia Emergence Scale to measure the ED phenomenon in children. The Pediatric Anesthesia Emergence Scale was tested for its psychometric properties and was found to be both reliable and valid in measuring ED in children postanesthesia.[18] In a randomized control trial evaluating ED in 120 pediatric patients undergoing sedation or GA for MRI and using the Pediatric Anesthesia Emergence Scale, Bong et al[9] explored the incidence of ED between single-dose dexmedetomidine and propofol. They found that in the dexmedetomidine group the incidence of ED was 42.5%, and in the propofol group, the incidence of ED was 33.3%. However, the differences in these incident rates were not found to be statistically significant.[9] Although there was no statistical difference in rates, the high rates of ED with both of these drugs are of particular concern. Although neither dexmedetomidine nor propofol was found to be a predictor of ED, the time it took for the child to awaken from sedation or GA was a significant predictor of ED.[9] The longer it took for the child to wake up from anesthesia, the lower the odds of ED.[9]

RECOVERY (AWAKENING) TIME. Researchers explored different drugs, such as sevoflurane, isoflurane, nitrous oxide, propofol, and dexmedetomidine, and the effects of awakening or recovery time and these studies are presented subsequently. In this review, five studies have specifically presented the effects of drug dosage, route of drug delivery, and anxiety-reducing strategies on improving awakening time and reduce recovery times. In three studies, researchers explored the use of propofol compared with other anesthetic agents or methodologies of infusion. Heard et al[11] explored the use of propofol versus isoflurane with nitrous oxide and found that children who received propofol had more rapid awakening time than isoflurane-nitrous oxide with fewer adverse events during emergence and recovery. However, the recovery times for the two drugs were similar. Similarly, Hassan et al[19] explored the effects of propofol infused intermittently versus continuously for children undergoing an MRI in an effort to understand the effects this drug delivery methodology had on total dose needed to keep the patient still and the child's recovery time. Less drug was used with the continuous infusion of propofol versus intermittent use. However, neither type of drug delivery method affected recovery time or MRI image quality.[19] For these two studies, the drug type, drug dose, or drug delivery methodology did not result in shorter recovery times. Cho et al[20] explored the use of a single-dose propofol protocol to a continuous infusion protocol to determine which methodology was more efficacious in shortening recovery times. In contrast to Heard et al[11] and Hassan et al,[19] the single-dose propofol protocol had statistically significantly shorter recovery times than the continuous infusion protocol ($P < .001$). However, this type of drug delivery method was found to be effective only for short-sequenced MRIs such as those lasting less than 30 minutes.[20]

Gyanesh et al[10] compared awakening time and time to discharge between intranasal dexmedetomidine, ketamine, and a placebo given preprocedurally in children undergoing MRI. They found that both the ketamine and dexmedetomidine had earlier awakening and recovery than did the children who received the placebo. The uses of these preprocedural drugs are thought to reduce (1) anxiety and fears before the procedure and (2) the amount of sedation or GA used during the actual MRI, thus improving awakening time and shortening recovery time.

Ogurlu et al[12] explored the use of headphones to reduce audible MRI noise in children undergoing MRI with anesthesia. The aim of this study was to reduce experienced MRI noise so as to reduce the amount of sevoflurane required to keep the child asleep during the MRI and, as a result, shorten the awakening time and discharge time from the postanesthesia care unit. They found statistically significant shorter discharge times from the postanesthesia care unit and faster awakening times with children who used the noise-reducing headphones ($P < .001$).[12]

In summary, drug types, dosages, and routes of administration used interprocedurally did not appear to have a significant impact on awakening times or recovery times. However, interventions used to reduce anxiety preprocedurally and interprocedurally appear to have a positive effect on awakening and recovery time. Although there are many strategies being explored to lessen the side effects of anesthetic drugs used for children undergoing MRI, the risks associated with sedation or GA remain.

EFFECTS OF SEDATION OR GA ON THE DEVELOPING BRAIN. For more than the past 15 years, researchers of animal studies explored the effects of anesthesia on the developing brain showing dramatic negative effects on neurodevelopment early in life and subsequent learning performance issues.[21,22] The generalization of the findings of animal studies to humans, however, has been criticized because of the differences in physiology between animal and human species. In addition, the environment in which animal laboratory research is performed is quite different from the practices of monitoring and controlling for the side effects of anesthesia in humans. Although findings from animal studies are difficult to translate directly to humans, they do provide the basis on which current physiological research related to pediatric anesthesia use is being explored.

The most crucial part of human brain development occurs in the third trimester of pregnancy up to the third year of life and continues through childhood. Human research has used primarily a retrospective methodology to evaluate these effects, mainly because of the large ethical issues of randomizing children with anesthesia use. There have been a few studies in which researchers used large data sets of children and retrospectively explored associations between exposure to anesthetics for surgical intervention, academic aptitude scores, and other biobehavioral challenges such as attention disorders.[22] Two studies in particular present the effects of anesthesia exposure in children. One found a statistically significant association with lower test scores and the other with incidence of attention disorders.[23,24] Although these findings provide a rationale for concern, the retrospective methodology cannot be used to explain a causal relationship.

The physiological effects of anesthesia on the developing brain have also been scientifically explored in primates. What has been hypothesized is that "by inducing apoptosis or interfering with the neurogenesis, anesthetic exposure during a critical period of neuronal development can have significant impact on neurocognitive function later in life."[22 p 1009] It is the exposure, duration of exposure, and type of drug used during this critical time period that leads to significant inhibition of neuronal development and causing anesthetic-induced developmental neurotoxicity.[22,25] Although the consequences of these effects on the human brain have yet to be determined, in primates, the prolonged use of anesthetics early in life has shown to increase apoptosis, neuronal death, and necrosis.[25] In addition to the physiological effects, the cognitive effects in primates have also been explored. Paule et al[26] investigated the lasting effects of ketamine administered during the first week of life in monkeys and found lower motivation and inferior performance in learning at age 7 months that continued until age 3.5 years.

In summary, animal research has sparked a concern with regards to the extent to which anesthesia affects the developing brain and the significance of that effect in humans. Regardless of the magnitude of the effect anesthesia has on the developing brain, any risk should be avoided when possible. There are times when the risk of not performing a procedure, surgery, or radiological test outweighs the risks of anesthesia for children. In those cases, strategies to reduce exposure to anesthesia must be implemented. New and emerging strategies are being explored to avoid anesthesia use during MRI specifically, where anesthesia is used primarily to ensure that the child remains still for the duration of the procedure. Descriptions of those strategies and their effectiveness in ensuring high quality magnetic resonance images are presented in the next section.

Nonsedation or Nonanesthesia Use in Pediatric MRI: The Emerging Evidence

There has been sporadic interest for more than the past 20 years to reduce the use of sedation or anesthesia in children receiving MRI. As the use of MRI for diagnostic clinical decision-making is growing, there is emerging interest to explore and test effective strategies to support children in successful MRI without sedation or anesthesia. The interest and the concerted exploration of these strategies stem from the growing concerns related to the side effects of the drugs used for sedation or anesthesia and the effects of sedation or anesthesia on the developing brain. Although the scant literature that does exist indicates that the risks for sedation or anesthesia in pediatric MRI are minimal, any risk should be avoided when possible. This review presents the empirical literature and explores the relationship of sedation or anesthesia-reducing strategies in children for MRI and their effectiveness on the outcomes measured.

A total of 16 empirical studies were evaluated: three experimental, five quasi-experimental, four retrospective reviews of existing data, one descriptive study, one quality improvement project, one systematic review, and one integrated review. Nine of these studies were conducted in the United States and five outside the United States. However, the one systematic and one integrated literature reviews that were conducted in the United States. included all relevant studies throughout the world. Excluding these reviews, 11 of the 14 studies measured the ability for children to obtain an MRI without sedation or anesthesia. Seven of these studies showed a statistical significance in reducing sedation or anesthesia use in children using modalities such as open versus closed MRI, mock MRI, audiovisual (AV) techniques, cognitive behavioral strategies, and parent partnership. Four were conducted in the United States, two in Australia, and one in the Netherlands. The results of these studies will be described in the next section.

STRATEGIES TO REDUCE SEDATION AND GA USE. In a systematic review that was completed and published in 2013 focused on understanding the strategies that are effective in reducing fear, anxiety, and claustrophobia in children who require an MRI and determining if those strategies were effective in reducing the need for sedation or anesthesia.[27] A total of eight studies met inclusion criteria for that review. These eight studies along with six additional studies will be presented in this section.

Open MRI versus closed MRI. There was only one study that presented the modality of an open MRI in reducing sedation or anesthesia use in children. Rupprecht et al[28] evaluated the effectiveness of an open MRI in reducing sedation rates compared with a closed MRI system. For children aged greater than 10 years, sedation rates were lower for open MRI than for closed MRI ($P < .0001$).[28] As this is the only study found that explored this modality, further exploration is needed to determine its efficacy in reducing sedation or GA for children.

Mock (practice) MRI. There were a total of five studies in which a mock MRI methodology was used as an intervention to reduce the need for sedation or anesthesia. Only one study presented the effects of a mock MRI protocol intervention of self-reported child distress. Rosenberg et al[29] used a mock MRI scanner to determine if preparation using a mock scanner decreased distress in children for MRI. All participants successfully completed the MRI without sedation. There were statistically significant reductions in heart rate and self-reported distress level during the simulator session and throughout the actual MRI ($P = .01$).[29] This provides early evidence that preparation with a mock MRI scanner before MRI may reduce self-reported distress in children.

Four studies compared the age of the child with her or his ability to successfully complete an MRI without sedation or anesthesia.[30] The researchers conducted a retrospective review to evaluate the effectiveness of a new mock MRI program and used a standardized mock scanner with cognitive behavior strategies in children aged 3 to 14 years living in Australia. Results showed a decreased need for anesthesia for children aged 3 to 8 years and a rate of anesthesia that was 16.8% lower than the nonmock MRI group ($P < .05$).[30] Although there were statistically significant decreases in anesthesia use in the age group 3 to 8 years, children aged 9 and older resulted in an increase in anesthesia use. This finding is of particular interest and may be best explained by limitations inherent in a standardized preparation approach rather than a patient-centered approach for preparing the child for MRI.

Bates et al[31] also used a standardized mock scanning approach along with other supportive preparation techniques specifically for children aged 4 to 7 years needing a brain MRI. Although the children were successful in completing the MRI without sedation or anesthesia, there was statistically significantly more motion artifact found for the nonsedated patients ($P = .02$).[31] The findings of these two studies are of importance as the results indicate that the use of a mock scanning protocol in young children may be an effective strategy to reduce the use of sedation or anesthesia in young children needing an MRI.

In the Netherlands, de Bie et al[32] used a mock scanner with standardized practice. They also found a positive relationship between the age of the patient and their ability to pass the mock scanner protocol. However, in contrast to Carter et al[30] and Bates et al,[31] de Bie et al[32] found that older children had a statistically significantly higher mock scanning protocol passing rate than younger children ($P = .026$).[32] Although these results contrast with those of Carter et al[30] and Bates et al,[31] all three studies provide initial evidentiary support that preparation using a mock MRI scanner before MRI can be useful in reducing the need for sedation or anesthesia in children.

Silva et al[33] also explored the use of a mock MRI to reduce the need for sedation or anesthesia in children who live in Australia. In addition to the mock MRI, other strategies used were a phone interview with the parent to understand the patient's specific needs, a storybook that showed pictures of the MRI and personnel, and procedural sensory information such as MRI sounds, an AV system, and parental contact during MRI.[33] The children were taught relaxation and coping strategies and had the ability to practice at home. With this preparation technique, 90% of the children passed the practice session, with 94% successfully completing their MRI without sedation or anesthesia.[33] This study, conducted outside the United States, provides the strongest evidence for a patient- and family-centered approach and the groundwork from which to further investigate this type of approach in the United States.

AV systems. Three studies presented the use of an AV system. A meta-analysis was performed for two studies for three different outcomes related to the use of an AV system modality.[27] Harned and Strain[34] examined the use of video goggles and earphones in reducing the need for sedation or anesthesia and the impact on time, throughput, and cost. They found a statistical difference in sedation or anesthesia use when comparing before and after use of AV MRI-compatible goggles. In addition, the results noted that in the age group 3 to 10 years, there was a decrease in sedation requirements ($P < .001$).[34] Likewise, there was a significant difference in the time they spent in the room, from a mean of 42 minutes for sedated patients to 35 minutes for nonsedated patients ($P < .0001$).[34] Lamaire et al[35] also explored the impact of video goggles and earphones on sedation rates in children for MRI. Results revealed an increase in pediatric patients scanned using an MRI ($P < .05$) and a decrease in sedation use of 15.4%. This decrease, was not statistically significant ($P = .32$), however does carry a clinical significance.[35]

The third study presented multiple approaches, one of which was the use of earphones and a video system. Ericson et al[36] evaluated using a patient-centered approach in a sample of 12 autistic children requiring an MRI. Results indicated that 97% of the older children were successful in completing the MRI without sedation or GA compared with 80% of the younger children. However, the success rate of completing MRI without sedation or anesthesia was not found to be statistically significant. The very small sample of participants in this study may have contributed to the lack of statistical significance nonetheless; these results provide the support for a patient- and family-centered approach that is individualized to the patient-specific needs.

In summary, all three studies resulted in a decrease in the use of sedation or anesthesia with the use of the AV systems modality. Although all studies depict clinical significance, only one study showed a statistically significant decrease. In addition, Harned and Strain[34] and Lemaire et al[35] were the only two studies found in this literature search that compared operational efficiencies (length of time in the MRI room and wait time for MRI) of sedated versus nonsedated children. A finding in both studies that is of particular importance is the statistically significantly better efficiency with nonsedated children than sedated children.

Cognitive behavioral therapy. The effectiveness of cognitive behavioral therapy was presented in three studies. Smart[37] used a randomized control trial methodology in which the intervention group used an audiotape that consisted of guided imagery, relaxation guides, and music; the control group did not have any audio. Seven of the 10 children in the intervention group completed the MRI procedure without sedation compared with 8 of the 10 children in the control group, who needed sedation to complete the MRI procedure.[37]

Tye et al[38] also used randomized control trial methodology. The intervention group received multiple cognitive intervention strategies whereas the control group received standard care. There were no statistically significant differences between the control and intervention groups in staff ratings or parents' ratings of distress.

In addition to the use of a mock scanner, Carter et al[30] used a play-based therapy desensitization, which included exposure to stimulus using age-based coping strategies at a pace appropriate for the child. They also taught the children breathing techniques and used cognitive strategies such as visual imagery. As discussed earlier, results support the use of these techniques in the 3 to 8 year-old group.

In summary, the use of cognitive behavior strategies in all three studies produced varying results. However, two of the three studies indicate that in the younger age groups, cognitive behavioral therapy addresses children's fears of the unknown and may play a role in successful pediatric MRI without sedation or anesthesia.

Photo diary. A randomized control trial performed by Hartman et al[39] explored the effectiveness of a photo diary on child and parent preprocedural stress and anxiety. No statistical difference was found in total anxiety between the control and intervention groups ($P = .16$) or total stress score ($P = .88$).[39] Results indicate that the photo diary does not reduce stress and anxiety in this population, but it may be helpful if used in combination with other strategies.

Patient- and family-centered approach. There were three studies in the United States that presented the partnership with the health care team and patients and their parents in developing an individualized approach to reduce sedation or anesthesia use for MRI. Two studies focused on autistic children, and one study was a data comparison of preimplementation and postimplementation of a sedation reduction program of children aged less than 7 years who required an MRI[40] partnered with parents of autistic children to understand the child's natural sleep patterns and attempted to mimic those normal patterns during MRI at night. Three of 45 children were not able to complete the MRI procedure with either video or natural sleep, yet 34 were successful on the first attempt.[40] Although this approach was clinically successful, the statistical significance of these findings was not presented.

Ericson et al[36] also used a patient-centered approach to evaluate autistic children (N = 12) requiring an MRI and found that older children were better able than younger ones to successfully complete the MRI without sedation or anesthesia. However, the results were not statistically significant. Nonetheless, these clinically significant results begin to provide support for the concept that engagement of the patient and their parent as a partner in care may result in safer options for children needing an MRI.

Kahn et al[41] evaluated the incidence of requiring sedation or anesthesia before and after the implementation of a program that used the expertise of a certified child life specialist, MRI video goggles, and a culture change that was described as emphasizing to all MRI staff avoidance of sedation or anesthesia whenever possible. Study results revealed a decrease in overall frequency of sedation or anesthesia and more specifically a statistically significant decrease in frequency of sedation in children aged 7 years and younger ($P < .001$).[41] This study supports the concept that a patient- and family-centered approach decreases the need for sedation or anesthesia use in children for MRI. Although two of these studies provide clinical support for the use of a patient- and family-centered care (PFCC) approach in autistic children, all three studies support the need for further exploration.

Although outside the date range for this review, published patient- and family-centered research is beginning to support the effects of using a PFCC approach to reducing anesthesia use in children for MRI in the United States. Most of the literature in the last 3 years is sparse, however, there are a limited number of additional published literature that support a patient- and family-centered approach to reducing anesthesia for children needing MRI. Jaimes and Gee[42] explored the success of a child life specialist preparation of a child needing an MRI. Child life specialists are masters prepared health care professionals that are trained in using a patient- and family-centered approach to preparing children for all aspects of hospitalization. In Jaimes and Gee[42], although no formal research and statistical analysis was presented, the authors found that preparing children for MRI along with adjusting sequencing of scans can reduce the need to sedate children.[42] Mastro et al[43] explored a sedation and anesthesia–free patient- and family-centered intervention effects on magnetic resonance image quality, health care costs, and the procedural time. Study results revealed that 96.8% of the images in the intervention group were of acceptable quality.[43] In addition, procedural times were statistically significantly shorter whereas health care costs were statistically significantly lower compared with the groups in which anesthesia or sedation was given.[43]

In summary, a few studies explored a methodology to reduce anxiety and distress for children requiring an MRI, and two studies tested the use of a patient- and family-centered approach to reduce anesthesia use in pediatric MRI. Of importance, it appears that the use of a comprehensive multimodal approach in diverse populations that varies based on the parent's or patient's participation, engagement, knowledge sharing of their child's individualized needs, and shared decisions of what is best for the child provides the best chance for successful completion of an MRI without anesthesia. The emerging evidence is beginning to support different modalities in reducing sedation or anesthesia in children requiring MRI. However, the gap in the literature related to the effects of a patient- and family-centered preparation intervention for children receiving an MRI in reducing the need for sedation or anesthesia requires further exploration. Nonetheless, these results begin to provide support that engagement of the patient and their parent as a partner in care may result in decreased use of sedation or anesthesia with no difference in the quality of the magnetic resonance image for some aggregate within the pediatric population.

Nursing's Role in Driving Patient Safety in Pediatric MRI

Research investigating the best methodology to reduce the use of anesthesia in pediatric MRI is just emerging, and there remains a limited number of studies testing approaches and exploring the outcomes of those approaches. On the basis of the literature presented, it is clear that there are potential risks to sedation or GA use in children and in particular in children whose brains are still developing. Pediatric MRI strategies that use a partnership approach with patients and their families appear to have the greatest potential to lead to the reduction of the use of sedation or GA in children. In a parsimonious theoretical PFCC model, it is proposed that when health care providers, such as nurses, create a trusting and caring relationship with patients and families while leveling the power gradient, patients and families become empowered to engage, share knowledge about their child, and become partners in decisions about care that ultimately lead to improved quality and safety outcomes.[44]

In driving patient safety, nurses are uniquely poised to be actively engaged in activities that reduce the use of anesthesia in children needing an MRI. Although using a patient- and family-centered approach is new and innovative, it also aligns with the national call to action to embrace a patient-centered approach to care. The findings of this integrative review of the literature provide support for using a multipronged yet structured methodology to create an individualized patient-centered plan to prepare the child for MRI. This methodology draws on the personal knowledge of the child and their family for the development of a personalized preparation plan to maximize the true potential of the child in successfully completing the MRI without sedation or GA. Individualized preparation and support during the MRI has shown to lead to successful completion of the MRI without sedation or GA.

The results of this review bring this standard practice under scrutiny. This review supports the proposition that health care providers should no longer assume young patients need sedation or GA to remain still enough to obtain an acceptable quality magnetic resonance image. Nursing plays an important role in designing, implementing, and evaluating interventions that reflect a patient- and family-centered approach to individualized MRI preparation and therefore advocating for the avoidance of pediatric MRI sedation or GA to promote patient safety.

Conclusions

The primary rationale for the use of sedation or GA in MRI is to ensure that the child remains still for the duration of time while the scan is being conducted. However, the use of sedation or GA is not benign and has real physiological and biological side effects for children. The safety risks and side effects of anesthetic agents used for children requiring an MRI include ED, respiratory depression, oxygenation, nausea, vomiting, agitation, and cardiovascular bradycardia. Of growing concern is the emerging literature exploring the effects of sedation or GA on the developing brain. The concern over these safety risks provides support to explore alternative options to sedation or GA for MRI for children. Although there are many strategies being explored to lessen the side effects of anesthetic drugs used for children undergoing MRI, the risks associated with sedation or GA remain.

Although the evidence is still developing, a multipronged yet structured methodology to create an individualized patient-centered plan to prepare the child for MRI appears to be successful. Furthermore, this type of approach aligns with the national call to action to embrace a patient-centered approach to care. PFCC has long been recognized as a concept that is vital to and inherent within nursing practice.[45] In addition, the American Nurses Association has strongly asserted that nurses are strategically positioned to advocate for PFCC within their practice organizations and should take the lead on the design and implementation of PFCC practices.[46] Heeding this call, it is important for front line clinical nurses along with clinical nursing leaders to design, implement, and evaluate the PFCC practices and their associated outcomes. It is these efforts that will improve the care provided to children and enhance child safety during MRI.

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