Tolerance of Esophageal Pressure Monitoring During Polysomnography in Children

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Objectives: To assess tolerance of esophageal pressure monitoring (EPM) among 5- to 13-year-old children during research polysomnography at study entry and again 1 year later.

Design: Prospective, observational study.

Setting: University-based sleep laboratory.

Participants: Children scheduled for adenotonsillectomy or hernia repair.

Interventions: None; all operations were performed for clinical indications only.

Results: Forty-two of 336 families approached about the study declined to participate mainly to avoid EPM. The EPM was usually the main concern for the 47 adenotonsillectomy and 7 hernia-repair patients and families who did participate. Among 54 enrolled subjects, 51 allowed attempts at insertion of the esophageal catheter, and insertion was successful in all cases; 38 tolerated EPM for at least 2 hours; 33 maintained EPM for the entire night; and 36 had repeat EPM 1 year later for at least 2 hours.

Reasons for EPM failure included crying at insertion, vomiting, pain, and inadvertent catheter removal during sleep. The children who tolerated EPM for at least 2 hours did not differ from other subjects based on age, sex, presence of a disruptive behavior disorder, anxiety, tonsil size, history of tonsillitis, or body mass index (all P > .05).

Conclusions: The EPM was well tolerated in most school-aged volunteers, but many families did not volunteer, and some children were not able to endure EPM for at least 2 hours. Although better success might be achieved in clinical settings if EPM is medically indicated and not part of voluntary research, EPM is still likely to create significant concern, for children and parents, that must be weighed against anticipated benefits.

Key Words: sleep apnea syndromes, sleep disorders, polysomnography, child, esophageal pressure monitoring

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INTRODUCTION

SLEEP-DISORDERED BREATHING (SDB) IS BELIEVED TO OCCUR IN 1% TO 3% OF CHILDREN1-3 BUT THESE ESTIMATES HAVE NOT INCLUDED UPPER AIRWAY RESISTANCE SYNDROME (UARS). The UARS is a form of SDB in which increases in respiratory event-related arousals, daytime sleepiness, behavioral morbidity, or other health-related consequences.4,5 Children may be at particular risk for UARS as opposed to frank obstructive sleep apnea syndrome.6 However, children with UARS are likely underrecognized,6 in part because sleep laboratory techniques necessary to detect increased upper airway resistance and UARS are not widely used.

Esophageal pressure monitoring (EPM) during polysomnography is the gold standard for detection of increasing upper airway resistance that leads to arousals.7 End-tidal or transternal CO2 monitoring, or pulse oximetry, may reveal obstructive hypventilation, but these methods miss many respiratory event–related arousals that are detected by EPM.8 Nasal-pressure monitoring may facilitate the diagnosis of UARS, but few data exist on the use of this methodology in children, and available reports suggest that signals are often lost due to obstruction with secretions, displacement of cannulas, or mouth breathing.9,10 In addition, some concerns have been raised about increased nasal resistance due to cannulas that may be large relative to small nasal passages.11 As a result, some sleep specialists now monitor esophageal pressure routinely on children evaluated for SDB.12 In general, however, pediatric EPM remains uncommon, partly because clinicians consider the technique to be invasive, frightening for children, and potentially disruptive of normal sleep architecture.13 Many children studied by polysomnography for SDB have enlarged, inflamed tonsils, whereas others have hyperactivity or other disruptive behaviors;14 any of these factors could further decrease the likelihood that EPM would be tolerated. In fact, few studies have investigated the feasibility of EPM during pediatric polysomnography. One retrospective study, which compared 10 children recorded with EPM to 10 matched patients recorded without EPM, found the technique to be successful, well-tolerated, and without substantial effect on sleep architecture.15

To better understand the extent to which EPM is tolerated in children, we tracked the experience of children who participated in an ongoing research study designed to assess the outcome-based value of several different variables that can be recorded during pediatric polysomnography. We then used demographic and clinical data to explore what factors might determine success or failure with EPM. The diagnostic value of EPM, along with that of several other polysomnographic measures, will be addressed fully in a future manuscript.

METHODS

Subjects

Children aged 5.0 through 12.9 years old were recruited from private and university-based pediatric otolaryngology and general surgery clinics in Ann Arbor, Michigan. Eight of the 9 otolaryngologists estimated to perform at least 90% of adenotonsillectomies (ATs) in Washtenaw County participated. To enroll in this study, children had to have been scheduled for AT (for SDB or other indications) or hernia repair (as a control). Children were excluded if they (1) required a polysomnogram...
for clinical purposes according to their physicians or surgeons, (2) had a history of treatment for SDB, or (3) had severe medical conditions that would preclude cognitive or polysomnographic assessment. Clinic clerks, nurses, or physicians briefly assessed participants’ potential interest in the study during clinic visits and faxed a referral form to the investigators, who then called identified parents, described the study, and extended an invitation to participate in a hands-on tour of the sleep laboratory for the child.

During the tour, children were allowed to see, touch, and handle electrodes, wires, sensors, and EPM catheters that were placed in a tray and carefully presented without disproportionate emphasis. Photographs of staff with esophageal catheters in place, with and without the additional sensors and electrodes required for polysomnography, were available at the time of the tour so that parents and children could see the relative sizes of the devices and understand what to expect. Prior to enrollment, parents signed informed consent documents, and children who were able to understand the study gave written assent for this Institutional Review Board-approved study. Whenever possible, by phone or fax, investigators collected some baseline historical information about all the potential participants identified by the surgical clinics, including those children who did not eventually enroll.

Procedures

Several days to weeks before the scheduled surgical procedure, each child and parent arrived at the sleep laboratory for an evening evaluation with a child psychiatrist, followed by a nocturnal polysomnogram. The polysomnogram was conducted in a large private room with a cot for the parent. Each child and parent pair was encouraged to make the visit a special event. They were advised to bring videotapes, games, books, bed toys, pillows, and other key sleeping aids from home. Selected technical staff experienced in pediatric polysomnography performed the studies. Prior to the studies, children took any routine medications, but none used a hypnotic. Stimulants were discontinued 10 days prior to the recordings.

Digital polysomnography included 4 electroencephalogram channels (C3-A2, C4-A1, O1-A2, O2-A1 of the 10-20 international electrode placement system), 2 electrooculogram tracing sites (right and left outer canthi), chin and bilateral anterior tibialis electromyogram, 2 electrocardiogram tracings, nasal and oral airflow (thermocouples), thoracic and abdominal excursion (piezoelectric strain gauges), finger oximetry (with viewable but not recorded pulse waveform), end-tidal CO₂, transcutaneous CO₂, and EPM. The latter was performed with a water-filled catheter, according to methods that have been described in detail. Hook-ups were performed in the subject’s sleep room with the child seated in an adjustable chair. All monitoring equipment, with the exception of the thermocouples, finger oximeter, and CO₂ sensors, was applied prior to placement of the catheter. Children usually had a parent and an investigator in the room during the procedure, along with any stuffed animals, videos, toys, or other distractions brought from home. Viscous lidocaine was usually administered by a technician into 1 nostril and “inhaled” by the child. A pediatric nasogastric feeding tube (6 Fr) was inserted to a distance estimated to leave the tip several centimeters above the gastroesophageal sphincter. Insertion of the catheter was performed by registered polysomnographic technologists experienced with both children and this technique. When a child did not react well to insertion of the catheter, parents sometimes withdrew consent for continued attempts. When parents were supportive, technicians exercised some discretion in the determination of how many times to try the insertion, but visibly upset or crying children were not asked to continue with the procedure for more than 10 minutes. Arm restraints were not used to prevent catheter removal by the child during the night.

During the day that followed polysomnography, a Multiple Sleep Latency Test and neuropsychological battery were administered. In the late afternoon, the child and parent were sent home with a $25 gift certificate to a toy store and a check for $100. Each child was scheduled to return for repeat postoperative testing under an identical protocol approximately 1 year after the surgical procedure.

Outcome variables included success or failure of EPM, the length of time for which it was tolerated, and EPM problems recorded by technicians. Contacted families who declined participation in the research protocol were asked to provide the primary reason for their decision. Willingness to provide parental consent and subject assent to the same procedure 1 year later were also recorded. Explanatory variables included age, sex, tonsillectomy versus hernia repair, tonsil size (considered large if rated by an investigator as 3 or 4 on a 4-point scale), the psychiatrist’s DSM-IV-based diagnosis of a disruptive behavior disorder (attention-deficit hyperactivity disorder, conduct disorder, or oppositional-defiant disorder), a widely used assessment for current anxious state (item 38 on the Children’s Psychiatric Rating Scale), socioeconomic status (Hollingshead, Yale Press, 1965), and body mass index (kg/height in meters²).

Analysis

Results were summarized as percentages or means and SD. Participants were compared to nonparticipants, and those who tolerated EPM for at least 2 hours to those who did not, by χ², Fisher’s exact, or t-tests. The 2-hour demarcation was chosen because esophageal pressures are usually most negative during deep non-rapid eye movement
sleep, which often occurs early in the night, and because the clinical experience of the investigators suggests that this is an approximate minimum duration that still allows useful inference based on EPM results. Analyses were performed with SAS, version 8.1 (SAS Institute Inc., Cary, NC). The level of significance was set at \( P < .05 \).

RESULTS

Subjects

Among 200 AT patients approached about the study, 47 (23.5%) enrolled in the research protocol; among 136 herniorrhaphy patients approached, 7 (5.1%) enrolled. The mean age of the 54 enrolled participants, 30 boys and 24 girls, was 8.43 ± 1.90 years; the range was 5.34 to 12.81 years. Among children scheduled for AT, comparisons between participants and nonparticipants revealed no significant differences in frequency of recurrent tonsillitis, frequency of suspected sleep apnea, sex, socioeconomic status, habitual snoring, or history of behavioral complaints (\( P > .10 \) for each). However, on average, participants were 1 year older than those who declined enrollment (\( P < .01 \)).

Esophageal Pressure Monitoring as a Barrier to Recruitment

A total of 336 patients and their parents were approached by clinic staff about participation in this study, and 278 (82.7%) agreed to be called by an investigator, but 224 (80.6%) of these then declined to participate in the research (Figure 1). Among contacted families who declined participation, 42 (18.8%) described EPM as the single most important factor in their decision; this represents 29.6% of the 142 families who gave any specific reason. Other concerns cited by these families included the potential stress of the overnight stay just prior to surgery, the length of the study visits (two 24-hour periods spaced 1 year apart), and conflicts with job, family, and school activities. Parents’ aversion to EPM was often notable, and the majority of refusals to participate came from parents rather than children, usually at the time of the initial telephone contact by the research staff. Most families (96%) who toured the facility ultimately enrolled in the research protocol. Among parents and children who did enroll, virtually all expressed some concern about EPM, but they asked far more questions about sleep disorders than about EPM.

Esophageal Pressure Monitoring

Insertion of the esophageal catheter was attempted, as required by the protocol, for 51 (94.4%) of the 54 enrolled subjects. In 1 case, the technician did not attempt catheter insertion because of the patient’s persistent crying. Protocol exceptions were made to allow participation of 1 child who had had multiple surgeries for a thyroductal cyst and 1 child whose parent refused any attempt at catheter insertion.

The catheter was inserted successfully in all 51 subjects, of whom 38 (74.5%) tolerated and maintained it for at least 2 hours of recording, 35 (68.6%) did so for at least 5 hours, and 33 (64.7%) did so for the entire preoperative polysomnogram. Figure 2 shows the duration of EPM for all 54 studied subjects. Comparison of children who tolerated EPM for at least 2 hours to those who did not showed no significant differences in age, sex, type of operation scheduled, presence of a disruptive behavior disorder, anxious state, tonsil size, history of recurrent tonsillitis, or body mass index (Table 1). However, the subjective impressions of an investigator who attended all catheter insertions (DLR) and the polysomnographic technicians who performed the procedure suggest that age and sex still may influence EPM tolerability in more subtle ways. For example, additional emotional support for younger children and girls appeared necessary to obtain a positive outcome. Many children reported that the viscous lidocaine was unpleasant because of mild nasopharyngeal irritation and a bad taste. In addition, the numbing sensation itself was alarming for some children with limited prior exposures to topical anesthetics.

Among the 13 subjects who attempted but did not tolerate EPM for at least 2 hours during their baseline polysomnogram, reasons included crying for 10 or more minutes during catheter insertion (\( n = 9 \)), vomiting (\( n = 4 \)), complaint of persistent nasopharyngeal pain (\( n = 2 \)), and sometimes associated coughing. In 4 instances, EPM was discontinued when the child inadvertently removed the catheter, typically during a confusional arousal, and the parent declined reinsertion.

Follow-up PolySomnography

Among the 54 children who underwent polysomnography before surgery, 53 (98.1%) returned for a repeat polysomnogram 1 year later. One child was lost to follow-up. The EPM was offered but not required during follow-up sleep studies. Parent or child objections resulted in omission of EPM in 17 (32.1%) of the 53 follow-up studies. Some of these 17 families initially declined to participate in the repeat study altogether, until further conversation revealed that the main hesitation was the optional repeat EPM. Among the 36 children who did agree to repeat EPM, all tolerated the catheter insertion and EPM for at least 2 hours; 33 tolerated it for the entire night with no reported adverse experiences. A total of 32 subjects had EPM for at least 2 hours both at baseline and follow-up (Figure 1).

DISCUSSION

This study of school-aged children who underwent EPM shows that EPM is most often well tolerated among research volunteers, but many potential subjects or their parents choose not to participate. All attempted catheter insertions were successful. However, a substantial minority

The level of significance was set at \( P < .05 \).

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<table>
<thead>
<tr>
<th>Variable</th>
<th>N=54</th>
<th>EPM Tolerated ≥ 2hrs</th>
<th>EPM Not Tolerated ≥ 2hrs</th>
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</thead>
<tbody>
<tr>
<td>Mean age ± SD, y</td>
<td>8.4 ± 1.9</td>
<td>8.7 ± 1.9</td>
<td>7.8 ± 1.7</td>
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<tr>
<td>Male, no. (%)</td>
<td>30 (55.6)</td>
<td>24 (63.2)</td>
<td>6 (37.5)</td>
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<tr>
<td>AT group, no. (%)</td>
<td>47 (87.0)</td>
<td>33 (86.8)</td>
<td>14 (87.5)</td>
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<td>Disruptive behavior disorder, no. (%)</td>
<td>19 (35.2)</td>
<td>13 (34.2)</td>
<td>6 (37.5)</td>
</tr>
<tr>
<td>Anxious state, no. (%)</td>
<td>20 (37.0)</td>
<td>14 (36.8)</td>
<td>6 (37.5)</td>
</tr>
<tr>
<td>Large tonsils, no. (%)</td>
<td>43 (79.6)</td>
<td>30 (79.0)</td>
<td>13 (81.2)</td>
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<tr>
<td>History of recurrent tonsillitis, no. (%)</td>
<td>10 (18.5)</td>
<td>8 (21.2)</td>
<td>2 (12.5)</td>
</tr>
<tr>
<td>Mean body mass index ± SD, kg/m²</td>
<td>19.4 ± 4.5</td>
<td>19.0 ± 4.5</td>
<td>20.3 ± 4.3</td>
</tr>
</tbody>
</table>
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* For each variable, the difference between subjects who did and did not tolerate at least 2 hours of esophageal pressure monitoring (EPM) was not significant (\( P > .05 \)) by \( \chi^2 \), Fisher’s exact test, or t test.

AT refers to adenotonsillectomy.
of these children did not tolerate EPM for at least 2 hours. If subjects
known to have declined participation in this research because of EPM
are added to those who tolerated EPM for less than 2 hours, 58 (60%) of
these 96 children could be considered to be EPM failures. Nearly all
children, whether or not EPM was accepted, focused on this procedure
as the most anxiety-provoking aspect of polysomnography, both before
and after the night in the sleep laboratory. Similar or worse experiences
could occur in clinical situations when young children may be forced
to undergo EPM with or without their assent. Although this study has some
limitations, it provides the largest published experience with tolerance of
EPM in children and should help clinicians decide whether to use the
procedure in clinical settings.

The most important barriers to EPM are clearly the attitudes, apprehen-
sions, and initial reactions to insertion of the catheter. When EPM
was discontinued because a child inadvertently pulled the catheter, the
desire to avoid reinserter was the main obstacle to continued EPM.
Important strategies to optimize acceptance of the procedure include
psychological and physical considerations. During catheter insertion, as
during the rest of the polysomnography hook-up process, children
should be entertained by videos, television, or other distractions. The
research protocol provided considerable preparation, coaching, and sup-
port, which may exceed that available in clinical practice settings. On the
other hand, 2 options that may be feasible in clinical practice but were
not in our research setting—exclusion of parents from the set-up room
during insertion and shortening of the process to less than 5 minutes—
may help considerably (personal communication, A. Giacomini,
RPSGT, Stanford Sleep Disorders Laboratory). The current study used a
6-Fr water-filled catheter to perform EPM, and this system may be bet-
ter tolerated than considerably thicker esophageal balloons that have
sometimes been used for the same purpose.13 Flushing the catheter with
warm water before insertion may make the catheter more pliable. The
application of topical viscous lidocaine may help with insertion but can
be an additional disagreeable experience for many children.

Several factors hypothesized to influence the chance of successful
EPM did not prove to be relevant; these included young age, female sex,
a disruptive behavior disorder, anxiety state, large tonsils, and history of
recurrent tonsillitis. To our knowledge, little information has been pub-
lished previously on factors that may predict children’s tolerance of
EPM or other minimally invasive throat procedures, such as phary-
goscopy. We speculate that parental acceptance of the importance and
feasibility of EPM is also critical to the success of the endeavor.

In practice, the decision of whether to use EPM during polysomnog-
ography in children hinges not only on its tolerability, but also on the value
of information to be derived from the procedure. Evidence that some
children suffer from sleepiness or behavior problems in association with
UARS is highly suggestive; some evidence implies that consideration of
respiratory event–related arousals in addition to apneas and hypop-
neas helps to predict excessive sleepiness in patients evaluated for
SDB.18 The UARS can be missed during polysomnography that moni-
tors breathing only with thermocouples or thermistors and piezoelectric
belts, the equipment most commonly used in clinical sleep laboratories.3
However, available data are not convincing that the gold-standard EPM,
rather than more-recently proposed, better-tolerated alternatives, is
required. In particular, nasal pressure monitoring may offer a reasonable
way to detect respiratory event–related arousals.7 One study compared
nasal pressure to EPM in 15 adults and concluded that results are simi-
lar, though nasal pressure detected nearly 20% more events than could
be confirmed by EPM.19 Data on nasal pressure monitoring in children
are scarce. Recent reports confirm its feasibility in the sleep laborato-
ry,9,10 but demonstrate suboptimal reliability in home ambulatory stud-
ies.20 One important concern with nasal pressure monitoring, particular-
ly in children, is that mouth breathing is ignored or, when 1 cannula is
directed toward the mouth, poorly detected. An optimal arrangement
may be to use nasal cannulas in combination with an oral thermocouple
or thermistor.

Other alternatives to EPM may include pulse transit time, the forced
oscillation technique, diaphragmatic electromyography, a suprasternal-
notch motion detector, or simply more sensitive scoring methods applied
to currently standard technology.12,22 For example, no study has ade-
quately compared EPM to results of thermocouple and piezoelectric
band-derived data scored such that hypopneas are defined by a 20%
decrease in any signal in association with an arousal or mild oxygen
desaturation. This sensitive definition of hypopneas potentially could
allow detection of subtle events otherwise detected only by EPM or
nasal pressure monitoring.

Finally, a consideration that limits the value of EPM, nasal pressure,
or any substitute is that published reports do not adequately define nor-
mal and abnormal results based on prediction of important childhood
outcomes. Most studies that discuss outcomes of SDB in children have
used thermocouples or thermistors, a minority have used EPM, and vir-
tually none have used nasal pressure. Outcomes related to levels of dis-
ease defined by results of 1 technique will not necessarily show similar
associations with identical levels of disease as defined by other tech-
niques. Furthermore, few published reports consider the possibility that
even if standard techniques do miss many respiratory event–related
arousals, results may correlate with more sensitive measures sufficient-
ly to allow equally effective identification of clinically significant SDB,
albeit with different cut-offs for abnormal findings.

Among limitations that must be considered in the interpretation of the
current results, the most important is that subjects and parents were vol-
unteers in a research setting, not patients referred to a sleep laboratory.
Inclusion criteria specifically required absence of a clinically determined
need for polysomnography. The majority of otolaryngology-referred
children were diagnosed at the bedside with SDB; clinicians did not con-
sider polysomnographic confirmation necessary, a point of view that is
highly prevalent among North American otolaryngologists though rare
among sleep specialists.11 Clinical settings, EPM ordered by a clin-
ician is considered necessary because the health-related benefit is judged
important to the individual child. Under such circumstances, the parents
are more likely than those of research volunteers to insist that catheters
be inserted and remain inserted for the duration of the night. Children
and technicians who know that the procedure is not “optional” may have
more success with EPM than do those who participate in research stud-
ies. Most of the research subjects were initially studied just before a
scheduled surgical procedure that may have increased their general anx-
xiety levels and apprehension about any medical intervention. On the
other hand, children looking forward to toy-store research rewards,
though not contingent on success with EPM, may have had some posi-
tive motivation that children studied for clinical purposes would not
share. In practice, children less than 5 years old are commonly referred
for polysomnographic assessment of SDB, and this group could be less
tolerant of EPM than were the older children in this study. We speculate
that the net influence of factors specific to research settings is likely to
reduce, rather than enhance, EPM success rates in children. The nature
of the problems that occur, however, is unlikely to differ between
research and clinical settings.

Considerable controversy exists, even in the near absence of relevant
published data, over how well EPM can be tolerated by children. The
current data begin to fill this void: despite evidence that EPM can pro-
vide important information,4,5,8 most sleep laboratories do not use EPM
for pediatric studies, mainly because of concern—largely unstudied—
that it is not well tolerated. Our data seem to suggest that EPM should
not be a barrier to polysomnography in most children who assent to EPM
in clinical practice. However, many families may not assent if given a
choice, and nearly all will have apprehension about it. Less-invasive
methods to acquire the same information would be preferable, if they
can be adequately validated. Until then, clinicians who decide whether
to use EPM must consider the desire for the additional information pro-
vided, current knowledge about potential substitutes for this gold stan-
dard, clinical characteristics for any individual that may affect tolerance
of EPM, and the knowledge that EPM probably will be the most prob-
lematic aspect of the sleep laboratory experience for children and fami-

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lies involved.

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REFERENCES