Objective: To determine whether water exposure causes middle ear contamination in patients with collar button tympanostomy tubes (TTs).

Method and Design: An in vitro model of a human head that contained an auricle, external auditory canal, tympanic membrane with TT, middle ear, eustachian tube, and mastoid cavity was developed. Two electrodes connected to an external ohmmeter resided in the middle ear to detect water entry. The model was tested with 4 types of water exposure: showering, bathing, hair rinsing, and swimming. Statistical analysis was performed by the Fisher exact test.

Main Outcome Measures: A positive test result corresponded to water entering the middle ear via the TT, confirmed by a resistance reading of zero on the ohmmeter. A negative test result indicated no change in the initial high resistance reading.

Results: No positive test results were obtained for showering (0 of 60 tests), hair rinsing (0 of 60 tests), or head submersion in clean tap water (0 of 60 tests). Ten positive test results were obtained for head submersion in soapy water (10 of 97 tests), which was statistically different from clean water ($P < .007$). Swimming pool depths of 30, 45, 60, and 75 cm elicited positive test results in 2 of 16, 3 of 18, 2 of 20, and 11 of 20 tests, respectively. A higher incidence of water entry into the middle ear occurred at depths of more than 60 cm ($P < .001$). No statistical difference between depths of 60 cm or less occurred ($P = .88$).

Conclusions: Showering, hair rinsing, and head submersion in clean tap water do not promote water entry into the middle ear. Submersion in soapy water increases the probability of water contamination. Pool water infrequently enters the middle ear with head submersion, but the incidence increases with deeper swimming (>60 cm). These data provide further evidence that many water precautions frequently advised in patients with TTs are unnecessary.


MYRINGOTOMY and tympanostomy tube placement (M/T) is one of the most common otorharyngological procedures performed today. Since B. W. Armstrong, MD, reintroduced middle ear ventilation tubes in 1954, their role in the treatment of otitis media has become well accepted. Indications, outcomes, and complications of M/T are thoroughly addressed in the literature. Postoperative otitis media remains the most common complication and leads to significant morbidity from the perspective of parent and child. Between 3% and 30% of patients with M/T develop postoperative otitis media, which some authorities attribute to water contamination of the middle ear via a patent tympanostomy tube (TT). Consequently, many physicians recommend restrictions or ear plugs for swimming, diving, or even bathing.

These beliefs spanned many years and remained unchallenged until the 1980s. Beginning with Chapman, results of retrospective studies showed that successful prevention of postoperative otitis media requires only limited water precautions or prophylactic use of medicated otic suspensions. Precautions include no use of external auditory canal (EAC) occlusive devices, surface swimming in chlorinated pool or salt water only, no diving or deep swimming, no exposure to soapy or contaminated water (i.e., lake water), and prophylactic use of otic suspensions after water exposure as necessary. In 1984, Pashley and Scholl demonstrated that elevated pressure (11.45-21.45 cm H$_2$O) in the EAC was required for entry of water into the middle ear via a TT. With the opening pressure of the eustachian tube (ET) described as 12 to 15 cm H$_2$O, rising pressure in the EAC must be overcome to allow middle ear contamination. Exposure to soapy water reduces the EAC pressure required for water entry by lowering the surface tension of the TT lumen.
METHODS

MODEL

An in vitro model of a human head with an auricle, EAC, tympanic membrane (TM) with TT, middle ear, ET, and mastoid cavity was developed (Figure 1 and Figure 2). An ear irrigating model by Adam Routiull Inc (Sittingbourne, Kent, England) served as the basis for our model. The model comprised a hollow, watertight replica of an adult human head, auricle, and EAC.

The model was modified by attaching the auricle and EAC to the head in a watertight fashion with epoxy and silicone putty. The EAC (3.0 cm long, 0.8 cm in diameter, and 1.5 mL in volume) was formed with epoxy to create an anterior slant from lateral to medial that correlates with the angled EAC in humans. The lateral 1 cm consisted of rubber, with the medial 2 cm being part of the acrylic apparatus attached within the hollow portion of the head. This apparatus was attached to the inside of the right lateral skull in a watertight fashion. The left lateral skull was formed by a removable molded fiberglass plate and seal.

Machined acrylic blocks (Figure 3 and Figure 4), cylinders, and a hypodermic 5-mL syringe plunger created a middle ear cavity with a variable volume by length (0.0-4.5 mL). A 35-mL hypodermic syringe barrel trimmed to 10 mL and attached to the middle ear cavity served as the mastoid cavity with a variable volume (0-10 mL). A Silastic sheet (Dow Corning, Midland, Mich) measuring 0.01-cm thick and 8 mm in diameter with a 0.3-cm² surface area represented the mobile area of the TM. A Sheehy-style collar button TT (Activent, XOMED, Jacksonville, Fla) with a 1.27-mm inner diameter resided in the anterior and inferior quadrant of the TM. An 18-gauge hypodermic needle tip and a 28-gauge surgical wire were secured in the middle ear 1 mm apart and 2 mm medial to the TM. Both served as electrodes to detect the presence of water in the middle ear cavity. The electrodes connected to electrical wire extending out of the model base and supporting pole, where they made contact with positive and negative plugs in the watertight cap. An ohmmeter (model 630, Triplett, Bluffton, Ohio) connected to the cap registered a high resistance when the middle ear was dry (200,000 Ω) and zero resistance when the middle ear was contaminated with moisture. The 18-gauge needle served as a functioning ET. The needle was connected by small bore plastic tubing to a glass tube, the end of which was placed below the surface of water in a vertical cylinder. By setting the position of the glass tube, the pressure required to overcome hydrostatic pressure, which would allow air escape, was adjustable. This was set to correlate with ET opening pressure (12-15 cm H₂O).

TESTING

The overall volume of the mastoid air cell system was determined to average 8.7 mL by Zwislocki in 1962 using impedance measurements in live patients. We, therefore, chose a mastoid volume of 7 mL and middle ear space volume of 2 mL to test our model. Four types of practical water exposure were evaluated: showering, bathing, hair rinsing, and swimming. A positive test result corresponded to water entering the middle ear cavity via the patent TT and was confirmed by a zero resistance reading on the ohmmeter. A negative test result indicated no change in the initial high resistance reading. Statistical analysis was done by the Fisher exact test.

Clean bathtub tap water was tested in the settings of head submersion (supine with the EAC 12.7 cm below the water level), hair rinsing (supine and prone), showering (supine and prone), and filling of the EAC. Soapy bathtub water was evaluated using head submersion (supine) and filling of the EAC. On-site chlorinated swimming pool water was first tested as the control at varying depths (30-90 cm) with an intact TM but no TT. The model, with an intact TM and a patent TT, was then evaluated at increasing depths (30, 45, 60, and 75 cm).

RESULTS

Exposing the model to daily practical activities involving clean tap water resulted in no positive test results (0 of 200 tests). These activities included submersion into bathtub water (0 of 60 tests), placement under a stream of running water (0 of 60 tests), showering (0 of 60 tests), and filling of the EAC (0 of 20 tests). Soapy water exposure increased the incidence of middle ear contamination via the TT to 14.6% (20 of 137 tests). Positive test results arose when the model was submerged in bathtub water (10 of 97 tests) and with filling of the EAC (10 of 40 tests). The increased incidence was statistically significant when comparing the EAC filled with soapy vs clean tap water (P<.007). When evaluating chlorinated swimming pool water, a control model with an intact TM was tested at varying depths (30-90 cm) and elicited no positive results (0 of 20 tests). Head dunking at depths of 30, 45, 60, and 75 cm yielded positive results in 2 of 16, 3 of 18, 2 of 20, and 11 of 20 tests, respectively. Comparing depths of 60 cm and less (7 of 54 tests) with depths greater than 60 cm (11 of 20 tests), a statistically significant difference arose (P=.001), but no significant difference was detected between depths of 60 cm and less (P = .88).

COMMENT

Most parents ask, “Can he get water in his ears?” when confronted with the recommendation for TTs. For gen-
erations, strict water precautions have been recommended, forcing parents to struggle with avoiding water exposure and assumed contamination of the middle ear. In turn, children have been restricted from swimming or have been forced to wear ear plugs during everyday activities involving water exposure.

Only recently has the otolaryngology literature, using prospective clinical studies, focused on disproving this myth (Table). No statistically significant differences in postoperative otorrhea were found in trials with swimming vs nonswimming, water exposure with protection vs prophylactic use of otic drops only, no water restrictions plus the use of otic drops, and swimming without ear plugs vs with ear plugs vs no swimming. In addition, other studies focused on depth of water exposure and diving. Lorusbury concluded that unrestricted surface swimming was less likely to cause postoperative otorrhea compared with deep swimming and diving (1 of 600 and 1 of 100 tests, respectively). Using an in vitro model, Pashley and Scholl found that increased depths led to increased EAC pressure, resulting in contamination of the middle ear via the TT. Salata and Derka et al also noted that the incidence of postoperative otorrhea was higher in children 2 years of age and younger secondary to the higher incidence of upper respiratory tract infections in this group. Children using ear protection actually had a higher incidence of otorrhea than children swimming without protection (Table). Brook and Coolbaugh described the use of EAC occlusive devices leading to increased bacterial colonization, which may be the source of increased otorrhea in these patients.

Our model dispelled the myth that all types of water exposure cause middle ear contamination. Exposure to clean tap water via head submersion, showering, and hair rinsing did not cause middle ear contamination. The likelihood of developing otorrhea in settings should be considered zero, thereby alleviating the need for ear protection devices. Our findings also support the results described by Pashley and Scholl. Soapy water decreased the surface tension of the TT, allowing infrequent middle ear contamination.
In the setting of swimming and water exposure, not only is water type a variable but water depth is a variable also. Increasing the pressure in the EAC increases the incidence of water entry into the middle ear via the patent TT. Pashley and Scholl attribute this phenomenon to the opening of the ET (12-15 cm H2O) relieving the resisting pressure trapped in the middle ear and allowing the inflow of water via the TT. We found that surface swimming (≤60 cm) had a 13% incidence of water entry in our model, whereas swimming in depths greater than 60 cm led to an increased incidence of 55%. This difference was statistically significant and may increase the chance of otorrhea. Our data also correlate with those of Lonusbury, who concluded that diving and deep swimming led to a higher incidence of otorrhea, yet surface swimming was found to be safe even without ear protection. Considering that most patients of M/T age are less daring than their older counterparts, most will likely surface swim only, thereby reducing their risk of middle ear contamination.

Our recommendations for water exposure in children with tympanostomy are as follows:

1. Showering, hair rinsing, and head submersion in clean tap water do not require EAC protection.

2. Protection of the EAC during bathing in soapy water is not necessary, although head submersion does increase the incidence of middle ear contamination and is not advised.

3. Surface swimming (≤60 cm) in chlorinated pool water without EAC protection is allowable. Because deeper swimming or diving significantly increases the likelihood of middle ear contamination, restrictions may be considered. Given the lack of evidence that water contamination actually leads to otorrhea, we do not advise restrictions unless a patient clearly develops suppurrative otitis media after water contamination.

4. Occlusive devices for the EAC have not been shown to reduce postoperative otorrhea in prospective clinical trials but have been found to increase bacterial counts of the EAC. Their only potential use is in children who have developed otorrhea after deep swimming or diving and wish to continue this practice.

5. Prophylactic use of otic antibiotic suspensions after water exposure is theoretically helpful in preventing otorrhea but has not been proven statistically significant in prospective clinical trials; therefore, it is not recommended on a routine basis.

These recommendations apply to patients with TT and do not necessarily apply to patients with TM perforations.

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