Definitive Diagnosis and Management of Axillary Hyperhidrosis: The VapoMeter and Suction-Assisted Arthroscopic Shaving

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Abstract
Background: Axillary hyperhidrosis is a benign, yet significant, disability that not only impairs social interaction but also affects occupational activities.
Objectives: The author provides a detailed description of axillary shaving, a procedure with proven results. He also describes the use of the VapoMeter (Delfin Technologies, Stamford, Connecticut), which accurately and easily measures sweating in g/m²/h.
Methods: Although a total of 45 patients have received this surgery since 2005, this report includes only the last eight patients (16 axilla) for whom both pre- and postoperative VapoMeter readings are available.
Results: The average preoperative VapoMeter reading was 473 g/m²/h (range, 98-998), which improved to an average of 58 g/m²/h postoperatively (range, 21-227). As a comparison, controls for all axilla had an average measurement of 23.7 g/m²/h (range, 18-31).
Conclusions: When combined with the effective surgical technique of axillary shaving, the VapoMeter provides an objective measure to both definitively diagnose and confirm results of the shaving. With this protocol, patients who require surgical intervention for their hyperhidrosis can be reassured that the procedure is indeed effective in improving their condition.

Keywords
hyperhidrosis, axillary shaving, eccrine glands, sweat, VapoMeter

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Hyperhidrosis may be defined as excessive sweating beyond the normal physiologic response to heat or emotional stimuli. Usually, sweat glands are stimulated when the body overheats, producing moisture that has a cooling effect due to evaporation. When there is an excessive amount of sweat produced beyond a person’s physiologic needs, severe social, psychological, and/or occupational dysfunction may occur. Normal quantities have been defined as less than 1 mL/m²/min.¹ In patients with severe hyperhidrosis, sweat production can even exceed 40 mL/m²/min.¹ Qualitatively, we can say that any sweating that so negatively affects the daily life of individuals that their normal interactions with the world around them are compromised is excessive.²

The greatest concentrations of eccrine (sweat-producing) glands are in the palms, axilla, and soles of the feet. Only about 5% of the glands are normally active at the same time, but there is great potential for excessive sweat production in any of these areas.³ The apocrine glands, located in the axillary and urogenital regions, are fewer in number; these become active in puberty. They secrete into hair follicles and produce a viscous, odoriferous fluid that cause malodor (osmidrosis/bromhidrosis) if overproduced. This condition is reported more frequently in the Far East, where it is equally as socially debilitating as hyperhidrosis. A third type of recently reported sweat gland is the apecocrine gland, which is seen only in the adult axilla and shares morphologic and functional features with both the apocrine and eccrine glands.⁴ These glands are histologically identical to apocrine glands, except in that they empty into the

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axillary surface. These unique glands of the axilla are found only in the subcutaneous tissue of the axilla and not the dermis—a fact of particular significance when considering the rationale for and effectiveness of axillary shaving in the treatment of axillary hyperhidrosis.

The causes of hyperhidrosis can generally be divided into two large categories: primary (for which there is no recognizable cause) and secondary (which can result from a host of etiologies noted in Tables 1 and 2). The focus of this report will be primary hyperhidrosis, the disease that has no known etiology. This type of hyperhidrosis is idio-pathic and related to excessive production of sweat by eccrine glands (hyperhidrosis) and/or abnormal body odor produced by apocrine glands (bromhidrosis).

Although hyperhidrosis was viewed as a benign, insignificant condition for years, it is now recognized as being extremely debilitating since it potentially impairs the social interactions and occupational activities of those affected. In addition to its dysfunctional liability, it is much more common than previously recognized. According to a recent US survey, 2.8% of the population (8 million people) suffers from systemic hyperhidrosis (craniofacial, axillary, palmar, and/or pedal); this includes 1.4% of the population with symptomatic axillary hyperhidrosis. One-third of individuals with axillary hyperhidrosis indicated that the sweating was so intolerable or barely tolerable that it frequently or always interfered with daily activities, decreasing the time they spent on leisure activities or work. Patients will go to considerable lengths to hide their condition, adjusting their lives to “work around” the sight and/or smell of axillary sweating. Hyperhidrosis is occupationally disruptive in that there is potential difficulty in gripping, shaking hands, and handling tools or paperwork; also, clothing must be changed frequently. These liabilities, in turn, affect career choices and severely limit or eliminate careers in education, sales, and marketing. Jobs that involve paper, metal, and electric or electronic equipment are equally unattainable. As the condition is not self-limiting, the patients are plagued with more emotional distress and frustration, as well as poorer coping abilities than normal controls. In short, quality of life (QOL) in all spheres can be significantly affected by this condition.

The significance of this problem is validated by QOL scales showing that hyperhidrosis is comparable to end-stage renal disease, rheumatoid arthritis, multiple sclerosis, and severe psoriasis. Recent data would suggest a familial component, with almost half of affected patients describing a positive family history. The disease has been linked to chromosome 14. It is found slightly more frequently in females than in males and most often occurs before the age of 25, though it has been described at birth. There is no ethnic or sociologic predilection.

Both patients and physicians may fail to recognize primary hyperhidrosis as a common and treatable disease. As part of the patient’s history chart, anatomic location(s), frequency, triggers, duration, previous lifestyle alterations, family history, comorbidities, and use of drugs known to produce sweating should all be identified. However, note that there is typically little to be found on the physical exam, other than excessive moisture in the affected area. Primary hyperhidrosis is defined as focal, visible, excessive sweating of at least six months in duration without apparent cause, with at least two of the following characteristics:

- Bilateral and relatively symmetric locations
- Impairment of daily activities
Figure 1. The handheld VapoMeter (Delfin Technologies, Stamford, Connecticut).

- Frequency of at least one episode per week
- Age of onset younger than 25 years (frequently in the teenage years)
- Positive family history
- Cessation of focal sweating during sleep

Until recently, there have been only three ways of establishing a diagnosis of primary focal hyperhidrosis: (1) gravimetric testing (literally weighing the moisture on a filter paper, which is tedious and impractical in the clinical setting); (2) the Minor-starch-iodine test, which consists of placing starch and iodine on the area (a test is considered positive if a purple-black color is produced within five minutes, but the results are not necessarily reproducible, and the test lacks objectivity); or (3) the ninhydrin test, which is based on the principle that ninhydrin reacts with amino acids in sweat, producing an impression that allows quantification via digital analysis of the image produced on paper.

Another method of evaluating the significance of hyperhidrosis in a patient is the hyperhidrosis disease severity index. This is a hyperhidrosis-specific questionnaire designed to assess how patients rate the impact of sweating on their daily activities. Responses are rendered on a four-point scale: (1) never noticeable, never interferes; (2) tolerable, sometimes interferes; (3) barely tolerable, frequently interferes; and (4) intolerable, always interferes. A high score indicates a severe impact on QOL. This scale should be administered before initiation of any treatment and used as a means for determining the potential impact of treatment. If the patient feels that the treatment has improved by one level (ie, from a “4” to a “3”), there is a 50% decrease in sweating, whereas a two-level improvement correlates with an 80% reduction in sweating.

Within the past few years, another method of measuring transepidermal water loss (TEWL)—the amount of water that evaporates from the skin surface during a period of time (g/m²/h)—has been reported. The VapoMeter (Delfin Technologies, Stamford, Connecticut) provides a practical, reproducible method of quickly assessing TEWL—in fact, within 10 seconds (Figure 1).

Although used in the cosmetic and antiperspirant industry for a number of years, it has only recently been employed in the evaluation of palmar hyperhidrosis. There have been no previous reports of its application in axillary hyperhidrosis, but it has been shown to objectively evaluate TEWL both before and after bilateral thoracoscopic sympathectomy.

**NONSURGICAL MANAGEMENT OF AXILLARY HYPERHIDROSIS**

Many treatments have been suggested for management of hyperhidrosis, indicating that no single method has been effective for all patients. Because of their availability, safety, affordability, and efficacy, first-line nonsurgical treatments include over-the-counter antiperspirants, followed by “clinical-grade” topical antiperspirants and oral agents. All of these conservative measures should be employed before resorting to more invasive treatments.

The most common prescription topical antiperspirant is Drysol (Person & Covey, Glendale, California), a proprietary aluminum chloride hexahydrate formula, but this treatment has the disadvantages of both a relatively short duration of effectiveness (three to four days), as well as local skin irritation. Another recently introduced topical antiperspirant with a lower concentration of aluminum chloride combined with 2% salicylic acid is marketed as Hydrosal (Valeo Pharma Corp., Kirkland, Quebec). It seems to be as effective as Drysol but is associated with less irritation of axillary skin. It is available only over the Internet, and no prescription is required.

Oral anticholinergic agents (ie, glycopyrrolates) can be effective but carry potentially bothersome and dangerous side effects, including dry mouth, blurred vision, orthostatic hypotension, and tachycardia. There are also relative contraindications to their use, including closed-angle glaucoma, gastroesophageal reflux, and cardiac insufficiency.

Iontophoresis, another nonsurgical treatment, relies on the direct passage of galvanic current through the skin submerged in water. Although useful in focal areas, such as the hands or feet, it is logistically unsatisfactory in axillary hyperhidrosis. Last, botulinum toxin A injections inhibit the release of acetylcholine at the neuromuscular junction and the sympathetic cholinergic nerve terminals that innervate eccrine sweat glands, thereby reducing sweat production. Although botulinum type A is predictably effective, it lasts only four to six months. Even so, it remains the treatment of choice for areas or conditions unable to be treated surgically (ie, the craniofacial area, Frey syndrome, the plantar fascia) or for those patients who are unable or unwilling to undergo invasive surgery.

**SURGICAL MANAGEMENT OF AXILLARY HYPERHIDROSIS**

When nonsurgical methods prove ineffective in axillary hyperhidrosis, consideration should be given to surgical
intervention. Local procedures involve various types of axillary resections, including en bloc excision of skin and subcutaneous tissue, excision of underlying subcutaneous tissue through an incision without any actual skin excision, subtotal skin excision with open removal of subcutaneous tissue, glandular laser destruction and curettage, and liposuction. These techniques have varying degrees of success but are still plagued by unacceptable morbidity related to axillary scarring, hematoma formation, skin necrosis, and limitation of arm movement. Endoscopic thoracic sympathectomy, an extremely effective surgery for palmar hyperhidrosis, has even been suggested.

Previously, the results of all of these techniques have been assessed by direct patient response and/or a mailed survey, both of which are subjective and lack reproducible objectivity.

An article by Tung described good results in the treatment of axillary osmidrosis with an arthroscopic shaver technique. Independently, Arneja et al reported a similar technique for axillary hyperhidrosis with excellent results. This procedure (also described herein), when combined with the objective measurement provided by the VapoMeter, offers the axillary hyperhidrosis patient the potential of permanent, objectively documented relief of his or her disability. The author has used the technique of axillary arthroscopic shaving in the treatment of hyperhidrosis since 2005 and, as with previous investigators, has found it to be extremely effective. Until recently, though, its success was based only on subjective information supplied by the patient. The author’s clinic, which enabled him to objectively measure the evaporation rate of water in g/m²/h. Here, results from a series of patients treated with both the VapoMeter and axillary shaving are reported.

**METHODS**

This study was approved by the Institutional Review Board of the Medical College of Wisconsin (Milwaukee, Wisconsin). Patients were included in the study if they had (1) a diagnosis of primary hyperhidrosis, based on patient history and VapoMeter readings; (2) a failure of conservative therapy; (3) no prior axillary surgery for this condition; (4) surgical treatment with the arthroscopic shaver technique; and (5) a minimum of three months of follow-up, including postoperative VapoMeter readings. There were no age, gender, or ethnicity criteria.

When this study began in 2005, the design called only for a patient survey to evaluate outcomes and a request for each patient to return to the clinic for a postoperative starch-iodine test. Since adding the VapoMeter in April 2009, all of the early, pre-VapoMeter patients have been asked to return for postoperative readings. For the later patients in the series, VapoMeter readings were incorporated into both the initial and postoperative evaluations for documentation of the short- and long-term results.

Twenty-nine patients were treated between March 2005 and March 2009, when the VapoMeter became available; an additional eight patients were treated according to the full study protocol between April 2009 and June 2010.

**Surgical Procedure**

As the offending sweat glands are associated with the hair-bearing area of the axilla, this area was shaved and marked before induction. The location of the 1-cm access incision, which lies in the anterior axillary fold, was also marked (Figure 2). Under general anesthesia, the patient was placed in a supine position with arms abducted to a 100-degree angle, taking care to avoid the risk of brachial plexus injury. Approximately 20 to 30 mL of 0.5% xylcaine with 1/200,000 epinephrine was infiltrated bilaterally, superficially enough to produce a wheal (Figure 3). This injection was important for hemostasis and short-term postoperative pain control. The patient was then prepped and draped, thus allowing sufficient time to maximize the epinephrine’s effects.

A 1-cm incision was made in the previously marked area of the anterior axillary fold. Using Metzenbaum dissecting scissors placed horizontally through the incision, a
superficial elevation of the hair-bearing axillary skin was made, leaving as little subcutaneous fat on the elevated flap as possible (Figure 4). This was done rapidly in a bloodless manner, taking care to make sure that there was a complete elevation of the flap in the outlined area. The suction-assisted cartilage shaver, a Stryker CORE powered instrument driver (Stryker, Kalamazoo, Michigan), was placed in the pocket (Figure 5). This shaver, commonly used in endoscopic orthopedic cartilage shaving of joints, consists of two concentric metal cannulae, one smaller than the other. At its tip, the outer, larger cannula has a half-opened portion that protects the sharp, inner, oscillating cannula. This allows the two cannulae to provide both continuous curettage and suction drainage, which is activated simultaneously with the rotating curette (Figure 6). The hand piece setting was placed at 900 rpm, its lowest setting. The shaving tip was always held upward (toward the undersurface of the elevated flap) to prevent injury to the deeper tissues. The best exposure was gained by operating the shaver from the head of the table, above the patient’s abducted arm. With the activation of the oscillating blade and suction, aspirate of subcutaneous tissue was obvious in the tubing.

Having an assistant provide stabilizing traction on the axillary skin during both the “scissor” flap elevation and the actual shaving helped to prevent any perforation of the axillary skin (Figure 7). This skin stabilization was very important, as it facilitated depth limitation to the subcutaneous fat on the deep surface of the dermis (which contains the offending sweat glands), while preserving the hair bulbs and associated dermal structures. On completion of the shaving, the skin was everted to document total removal of the subcutaneous tissue and preservation of the integrity of the axillary skin (Figure 8).

A soft, small-caliber drain was inserted through the incision, the skin was closed with a simple nylon suture, and a sponge pad was secured in the axilla with silk sutures to provide external pressure (Figure 9). Both the drain and the externally applied pad were removed 24 hours later in the clinic. The entire procedure was completed within one hour. Most patients reported feeling little pain; regardless, analgesics were prescribed. When the external
dressing was removed, the patients noted cessation of sweating. Patients were asked to limit abduction of their arms for one week after surgery. Sutures were removed at five days. The usual absence from employment following surgery was about four days. Each patient was followed up at three-, six-, and 12-month intervals. VapoMeter readings were obtained at each return visit.

A video of the surgical procedure is available at www.aestheticsurgeryjournal.com. You may also use any smartphone to scan the code on the first page of this article to be taken directly to the video on www.YouTube.com.

**RESULTS**

During the first four years in which the author performed axillary shaving for hyperhidrosis, the only means of determining the degree of disability associated with hyperhidrosis was by patient history, which was very subjective. Patients were simply asked to quantify how the condition affected their lives on a 1-to-10 scale, with “1” being normal and “10” being intolerable. Although the 29 patients who underwent axillary shaving between March 2005 and March 2009 with this criterion were very pleased with the results, the lack of objective documentation was bothersome.

With the acquisition of the VapoMeter in April 2009, the inaccuracy and subjectivity of the measurements in previous years were eliminated. Therefore, in this report, we quantified only the pre- and postoperative data of patients in this later part of the series. There were a total of eight patients (16 axillae) for whom complete results are available. Seven of these patients were females and one was male. The average age of the patients was 22 years (range, 12 to 35), and the average follow-up duration was eight months (range, three to 12). The average preoperative VapoMeter reading was 473 g/m²/h (range, 98-998 g/m²/h); the average postoperative reading at the time of the last visit at six months was 58 g/m²/h (range, 21-26 g/m²/h). Controls for all axillae had an average measurement of 23.7 g/m²/h, with a range of 18 to 31 g/m²/h.

Although not all of them were included in this study, the author treated a total of 45 patients with axillary shaving between April 2005 and June 2010. Complications included one infection, which was treated with antibiotics, and one postoperative hematoma, which had to be drained in the operating room. No hypertrophic scarring, alopecia, or numbness was associated with the surgery. Although they initially had a good response, two patients experienced a recurrence of symptoms (and elevated VapoMeter readings) after three months and 24 months, respectively; both responded well to reoperation.

**DISCUSSION**

Axillary hyperhidrosis results in significant social, occupational, emotional, financial, and psychological distress for millions of people in the United States. In patients with primary (idiopathic) hyperhidrosis, the condition typically starts at puberty but can also have an onset in the late teens or 20s. There is often a hereditary component. Focal hyperhidrosis of the axilla is particularly bothersome, as it causes these young patients embarrassment and can restrict their social development. It also limits the color and type of clothing to dark, sleeved garments. Many of these patients do not seek medical attention because they are self-conscious and think that they “just sweat a lot.” A recent study suggests that patients with hyperhidrosis are at high risk for secondary infections related to the disease.35

Many primary care physicians have little knowledge of the scope of treatment options available for axillary hyperhidrosis. When patients are referred to a dermatologist, the options considered are usually nonsurgical, even though these offer only temporary relief. These interventions
are sufficient for some (even many) patients, but there are certainly patients who find topical antiperspirants messy or ineffective or who desire a more permanent solution than repeated botulinum toxin injections. In these patients, direct, surgical, end-organ intervention in the axilla is appropriate.

The ideal procedure should permanently relieve the problem; be minimally-invasive, simple, and predictable; and have minimal morbidity and scarring. As Baumgartner\textsuperscript{12} states, “The key factor is to remove the sweat glands responsible for the pathology with as little trauma as possible.” Based on this author’s experience and that of others,\textsuperscript{39} axillary shaving seems to be that ideal procedure. It is a simple outpatient operation with minimal morbidity and long-lasting results because it disable/ablates the offending sweat glands. It is covered by most third-party payors (CPT Code 11450). Other techniques such as liposuction have limited effectiveness and carry the potential of damage to axillary structures with the action of the suction cannula.

In previous reports, objective documentation of axillary sweating was limited to either a tedious gravimetric measure of the weight of sweat produced or the subjective, rather gross measure of color change noted with the starch-iodine test. Outcomes were evaluated based on subjective patient surveys.\textsuperscript{34} The data provided in this report objectively document changes based on output from the VapoMeter, which produces readings that are extremely accurate and reproducible, measures the relative humidity (g/m²/h) of the axilla, and allows comparison with adjacent, non-hair-bearing skin as a control. Pathologic readings of hyperhidrosis will typically be five, 10, or 20 times greater than the control. This provides patients with assurance of the authenticity of their condition, while providing the clinician (and third-party payors) with objective evidence of a legitimate disease process before surgery and success after surgery. Results from this study confirmed that axillary shaving for hyperhidrosis is a simple, safe, efficient, effective, and dependable outpatient procedure with minimal morbidity that typically reduces the amount of sweating tenfold, thereby providing these patients a degree of normalcy in their lives.

Of note, the VapoMeter also provides clinicians with a postoperative tool for evaluating patients who have undergone axillary shaving but still complain of excessive sweating. A near-normal reading (generally, two or three times greater than the control) reassures the patient of the effectiveness of the procedure as compared to their preoperative readings. Of course, if there is documented recurrence of pathologic levels (10 to 20 times above the control), objective evidence is thus provided to justify a repeat procedure. In this series, resumption of symptoms occurred in two patients (at three months and at two years postoperatively) after an initially excellent response to the first procedure. Both have since undergone a repeat shaving and are free of symptoms, with normal VapoMeter readings. We have no more explanation for this than we have for the etiology of primary hyperhidrosis.

CONCLUSIONS

Until recently, the only practical way to diagnose and assess the results of hyperhidrosis treatment was through patient history before and a survey after surgery, both of which introduced a significant degree of subjectivity. When combined with the effective surgical technique of axillary shaving, the VapoMeter provides an objective measure to both definitively diagnose and confirm results of the shaving. This documentation is important in providing third-party carriers with quantifiable data to justify insurance coverage and in reassuring patients who may question the effectiveness of the operation. It also provides a necessary element of science to an otherwise subjectively driven surgical intervention. As surgeons, we should be aware of this cohort of patients with a serious malady that can be easily treated with a simple, minimally-invasive procedure that is reimbursable and provides predictable results in otherwise healthy, young, and grateful patients.

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