Objective: To identify surface landmarks that can serve as reference points to the underlying musculature in the treatment of glabellar rhytids.

Methods: Fifty cadaver hemibrows were dissected to assess the location, disposition, and relationships of the brow muscles, along with their variations at each of several consistent locations. Particular attention was paid to the corrugator supercilii, frontal belly of the frontalis, and procerus muscles.

Conclusions: The information gained here may be applied to the pharmacological or surgical treatment of glabellar rhytids. Knowledge of the frequent location of the muscles involved, relative to easily identifiable surface landmarks, allows a more precise approach.


The glabella occupies a relatively central position in the face and therefore easily attracts the attention of patients and their observers. Rhytids in this region, which range from fine lines to deep furrows, may result in the patient being incorrectly seen as angry, anxious, fatigued, fearful, or of advanced age. Most commonly, glabellar rhytids are dynamic in nature. These hyperfunctional lines are a result of the pull on the skin by the underlying facial musculature. This is in contrast to facial wrinkles in other areas, which result from age-induced changes in the collagen of the dermis. While the latter are frequently sequelae of sun damage and aging in an older population, hyperfunctional glabellar lines may be seen in younger patients, aged 20 to 50 years.

Individuals present with different patterns of rhytid formation according to their habits of facial expression and resting facial posture. The vertically oriented procerus muscle is thought to make the greatest contribution to the formation of horizontal glabellar furrows, while the corrugator supercillii muscles produce the vertical rhytids in this region. There may be some contribution from a muscle identified as the depressor supercilli, but descriptions of this muscle are few, bringing its existence as a distinct entity into some question. The elastic properties of the skin and factors associated with photoaging contribute to rhytid formation but play a much less important role.

A variety of direct surgical approaches have been used for the eradication of glabellar rhytids since the 1920s. This type of procedure allows direct visualization of the muscles to defunction or excise them. The coronal lift has fluctuated in popularity during the years. For a long time, it was the only approach for elevation of the eyebrows, as well as correction of the vertical and horizontal wrinkles in the glabella. Suspensive forces from the forehead lift contributed to making the glabellar area smoother, but muscle ablation was found to be essential. However, patients without brow ptosis or forehead rhytids, who do not need or want a brow lift, are often reluctant to agree to a coronal incision with its attendant scarring, morbidity, and recovery time.

Postsurgical patients are occasionally able to contract residual corrugator or procerus muscles, either in the early postoperative period or within 3 to 4 months. This produces either a recurrence of the initial complaint or a localized hornlike prominence along the eyebrow that may be caused by the formation of a scar tissue “bridge” between divided muscle segments. Alternatively, this may result from incomplete resection or transection of the involved muscle groups. In response to this situation, more direct, limited surgical ap-
MATERIALS AND METHODS

Twenty-six cadavers were selected at random from the University of California at San Francisco Department of Anatomy Laboratory. There were 12 males and 14 females. Cadavers had undergone preservation in the standard method and had had no previous dissection of the head and neck. Complete dissection of the glabellar region of the first female cadaver was carried out to confirm the relationships between the regional muscle groups. Each remaining cadaver provided 2 sets of brow musculature, thus providing 50 hemibrows for evaluation.

Methylene blue was used to mark each cadaver along parallel sagittal planes through the midline of the nasal dorsum, the plane of the medial canthus, the plane of the midpupillary lines, and the plane of the lateral canthus (Figure 1). Incisions were made with a sharp No. 10 blade scalpel along these demarcated planes from skin to frontal periosteum (Figure 2). Dissections and measurements were done by a single prosector (M.R.M.) who was blinded to the accumulating results. Measurements were made by means of a steel caliper and steel ruler in millimeters and included the following: corrugator supercilii depth from skin; corrugator supercilii muscle belly thickness; frontalis muscle depth from skin; procerus muscle length; and procerus muscle depth from skin. The measurements related to the corrugator and frontalis were taken at each of 4 locations (if present): midline, medial canthus, midpupillary line, and lateral canthus. The procerus muscle was measured in the midline only. Additionally, the position of the predominant bulk of corrugator muscle relative to a transverse line through the eyebrow was assessed at the plane of the medial canthus. Random specimens were reevaluated to ensure internal consistency of measurement. Data were recorded in preconstructed data tables. Once the measurements were completed, the brow musculature was dissected to make qualitative observations about the relative muscle orientation, position, origins, and insertions.

Statistical analysis of muscle measurements relied on Student’s t test (2-tailed) for individual samples. Any missing data were pairwise deleted. In addition to comparison among measurements within each category, measurements in males and females were compared across each category. Qualitative observations were, of course, not subjected to statistical analysis. However, descriptive trends regarding muscle size and position were observed.

Other attempts at correction of rhytids in this region have included direct excision, leaving unsightly scars or abnormal facial motion. Alternatively, tissue “fillers,” such as silicone, collagen, suture material, fibrin, polytetf, and autologous fat, have been used to lessen the cosmetic deformity. These treatments do not address the underlying facial musculature that produces the functional lines.

Botulinum toxin type A (Botox; Allergan Inc, Irvine, Calif) is a neuromuscular blocking agent that induces a flaccid paralysis when injected into striated muscles. This toxin was first used in the 1970s in the treatment of strabismus. In the 1980s, its use was expanded to the treatment of other facial dystonias, such as blepharospasm, hemifacial spasm, and oromandibular dystonia. More recently, its use in the treatment of hyperfunctional lines of the face has been introduced as a simple, noninvasive alternative to surgery or fillers. Carruthers and Carruthers first advocated its use in the treatment of glabellar frown lines in 1992. This method has been effective in producing excellent temporary results. However, application of botulinum toxin to this area is still in its relative infancy, with precise dosing and administration techniques still under active investigation.

The results of medical and surgical approaches have been varied in terms of initial effectiveness and duration of action. After surgical resection of a portion of the involved muscles, a scar may bridge the gap during the healing process so that reanimation occurs. Alternatively, the muscle groups that cause the rhytids may be incompletely resected. Similarly, under normal
circumstances, initial botulinum toxin treatment may last from 3 to 6 months.\textsuperscript{17-20} Failure of botulinum toxin therapy or short duration of action may occur despite the use of electromyographic (EMG) localization of the muscle. In this case, the EMG enables nonspecific identification of muscle activity. Even if the EMG is used during the appropriate facial expressions to accentuate the rhytids in this area, it does not guarantee proper placement of the injected botulinum toxin. Furthermore, the rare complication of upper eyelid ptosis may be caused by improper placement with migration of the toxin through the orbital septum so that the levator palpebrae superioris is affected. For both the surgical and medical approaches, an understanding of the relevant anatomy—the muscles involved and their positions relative to each other, as well as to adjacent structures—is critical. An accurate knowledge of the specific anatomy relative to surface landmarks is particularly important when blind or even EMG-guided botulinum toxin injections are used, yet most descriptions of this region are vague.

The purpose of this study was to examine the glabellar musculature in detail to provide a clear understanding of its relationships to surface landmarks. To improve the management of functional rhytids in this area, an accurate knowledge of this anatomy is important.

\textbf{RESULTS}

Initial dissection of the glabella, to establish the relationships between the various muscles in this region, is demonstrated in Figure 3. In the medial canthal area of the glabella, the thin frontalis was the most superficial muscle encountered, with the more bulky corrugator supercilii located deep to it. The corrugator was easily followed as it passed along a plane slightly oblique to the horizontal, along the superior orbital ridge. It was identified in 2 forms. It could be found as a short, narrow pyramidal muscle located at the medial end of the supraorbital ridge or as a long, narrow, straight muscle extending along the supraorbital ridge to or just beyond the midbrow position. Laterally, it interdigitated with the frontalis muscle before inserting into the skin of the midbrow or the medial half of the brow. Medially, the corrugator became confluent with the procerus muscle. No isolated vertical component of the corrugator was identified medially. The frontalis muscle had a relatively uniform depth and was attenuated in the midline, where it interdigitated with the procerus. The procerus muscle was identified as a small, thin pyramidal muscle arising from the tendinous fibers that cover the inferior portion of the nasal bone and the upper lateral nasal cartilage. Its insertion was into the skin between the eyebrows. Its fibers, oriented vertically, became continuous above the

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{figure3.png}
\caption{Initial dissection was performed to identify the relationship between the various muscles in the glabellar region. Here, scissors are passed deep to the corrugator supercilii.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{figure4.png}
\caption{Average findings for corrugator thickness.}
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\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{figure5.png}
\caption{Average findings for corrugator depth.}
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\begin{figure}[h]
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\includegraphics[width=0.8\textwidth]{figure6.png}
\caption{Corrugator position relative to a transverse line drawn through the midhorizontal eyebrow.}
\end{figure}
nose with the medial fibers of the frontalis. The width of the insertion varied and overlapped the medial frontalis muscle edges in most specimens. No distinct depressor supercili was identified.

Average findings for the various measurements are seen in Figure 4 through Figure 8. Corrugator muscle thickness varied significantly with measurement position in both male and female specimens. The thickest portion of the muscle belly was found at the medial canthus ($P<.05$). Substantial muscle bulk was still present at the midpupillary line, but no distinct corrugator fibers were detectable at the lateral canthus or in the midline. When the depth of the corrugator muscle from the skin surface was compared, no statistically significant differences could be found between medial canthal and midpupillary locations. These results were consistent with qualitative observations from careful dissection of this muscle. The muscle was thickest near its periosteal origin medially and tapered as it traveled laterally. Of note, in all specimens, the bulk of the corrugator muscle belly was at or slightly above the plane of a transverse line drawn through the mideyebrow (Figure 6). In the male specimens, 13 were even with this transverse line, while 11 were above it. In the female specimens, 10 were even with and 16 were above the transverse plane of the mideyebrow.

The procerus was fairly consistent in thickness ($\leq 1$ mm) throughout its course. The depth ranged from 1 to 4 mm, with an average of 2.8 mm and 2.5 mm in male and female specimens, respectively. While this difference was not statistically significant, the difference in length was: the average length for females was 19.1 mm compared with 16.4 mm for males ($P<.01$).

The frontalis muscle had a uniform depth, with no significant difference between measurements at the various locations within each specimen. However, the depth range among specimens was 2 to 7 mm.

**COMMENT**

Since glabellar rhytids are largely functional, effective management must address the cause rather than simply the effect. In doing so, complications related to lid or brow ptosis must be avoided. As a result, surgical approaches, whether transpalpebral or through a forehead or brow lift, depend on detailed knowledge of the related anatomy to guide direct visualization of the involved muscle groups and avoid the neurovascular “danger zones.” Transcutaneous soft-tissue augmentation or focal paralysis with the use of botulinum toxin is performed without this advantage.

Thus, anatomical knowledge of the area relies on appropriate surface landmarks. The nerves of surgical importance in the area are the supraorbital, supratrochlear, and infratrochlear nerves, and the corrugator supercili and procerus muscle motor branches.\(^8\) Collagen, autologous fat, and silicone, if injected into the retinal circulation, may produce embolic necrosis of the retina and blindness. This has been reported with injectable collagen\(^{21}\) and autologous fat.\(^{22}\) No embolic damage to the retina, optic nerve, or other surrounding structures has been reported with the use of botulinum toxin type A. This may be, in part, because this material is completely dissolved in sterile saline without preservative and the injection volume is small.

Response to botulinum toxin injection in the glabella does not appear to be prevented by patient immune defense mechanisms. Antibodies to botulinum toxin type A have been described in patients receiving large doses for long periods,\(^{23}\) but the smaller doses used in this region have not resulted in antibody production with similar procedures. Rather, the occasional lack of response to botulinum toxin injection may be caused by placement error.\(^{17,18,20,24}\) In these cases, injection or migration of the toxin into the postseptal space of the orbit is also possible, with resultant complications. In the present study, surface landmarks that were relevant to the involved musculature, but remain consistent and easily identifiable from specimen to specimen, were chosen for evaluation. Hence, the lateral canthus, midpupillary line, medial canthus, and midline were selected. The lateral canthal region served as a baseline measurement for the corrugator supercili since this muscle was not expected to be present at this location. The corrugator turns sharply toward its insertion in the skin in the region of the midbrow; however, since the midpupillary line is medial to this point, the corrugator muscle was still present at this landmark in all but 1 specimen. This is not always apparent in the usual anatomical depictions of the area. The clinical significance of this finding...
TABLE
Anatomical Findings and Clinical Applications

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Finding</th>
<th>Application</th>
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<tbody>
<tr>
<td>Corrugator supercili</td>
<td>Vertical rhytids</td>
<td>Treatment directed medial to this landmark</td>
</tr>
<tr>
<td></td>
<td>Insertion: at or medial to midbrow</td>
<td>Treatment directed lateral to this region (ie, does not extend to midline)</td>
</tr>
<tr>
<td></td>
<td>Origin: junction of frontal and nasal bones</td>
<td>Treatment focus</td>
</tr>
<tr>
<td></td>
<td>Bulkiest portion at medial brow with significant component at midpupillary line</td>
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<tr>
<td></td>
<td>Muscle belly at or above horizontal plane through eyebrow horizontal rhytids</td>
<td>Direct treatment at or above this plane to avoid ptosis</td>
</tr>
<tr>
<td>Procerus</td>
<td>Thin, narrow, depth of 1-4 mm</td>
<td>Treatment directed at midline, adjacent to skin</td>
</tr>
<tr>
<td></td>
<td>Longer in women than men</td>
<td>More attention must be given to procerus muscle in women</td>
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is that this muscle can largely be ignored beyond the mid-brow but requires attention at the midpupillary line where significant muscle bulk remains.

While the insertion of the corrugator supercili was variable, the origin was relatively consistent at the junction of the frontal and nasal bones, near the superomedial orbital rim. The contracted corrugator can often be felt between the examiner’s finger and thumb, as well as seen as a bulge in the region of the medial aspect of the brow. This is consistent with our finding that the bulkiest portion of this muscle belly lies here. Many anatomical drawings depict a vertical component to the corrugator medially. Our dissections did not substantiate this. Similarly, although some authors suggest existence of a depressor supercili in this region, this muscle was not identified as a distinct entity in our specimens.

Evaluation of the horizontal position of the corrugator yielded interesting results. The bulk of the muscle belly was invariably at or above the plane of a transverse line drawn coronally through the middle of the eyebrow. This information is useful in avoiding posttreatment ptosis with botulinum toxin injections. The needle should be directed at or slightly above this midbrow plane to achieve maximum effect while avoiding injection or migration of toxin through the orbital septum.

The procerus muscle is thin and narrow. However, its relatively consistent depth (1-4 mm) and midline location make it an easy target. The finding that the procerus was significantly longer in women than men was unexpected. This may explain our clinical observation that women, more than men, complain of transverse rhytids at the nasal base.

The summary of anatomical findings in the Table may be applied to any approach for management of rhytids in this region, but it is particularly relevant to blind, transcutaneous injection of botulinum toxin type A. Activation of the involved muscles by frowning aids in the general localization, but once this is established, surface landmarks may serve as further guidelines, with occasional modification dictated by clinical judgment. Although an EMG neuromuscular stimulator attached to an EMG needle or a gated muscle detector can be used to identify the most active part of the muscle precisely, many clinicians have not found this to be necessary. The use of accurate anatomical landmarks should produce confident, consistent results. Figure 9 demonstrates appropriate injection sites based on these landmarks. Specifically, for vertical glabellar rhytids, injections should be into the thickest portion of the corrugator supercili muscle adjacent to the medial aspect of the brow and even with or above the horizontal plane passing through the eyebrow. For horizontal rhytids, the procerus should be injected in the midline, slightly caudal to the root of the nose. The selection of sites must, of course, be influenced by clinical judgment during activation of the involved muscles with or without an EMG stimulator.

The findings of this study give detailed anatomical support for improved methods of treating rhytids in the glabellar region. They also stimulate a number of questions for future investigation: With more accurate placement, can the therapeutic dosage of botulinum toxin be reduced? Should the botulinum toxin be injected along the length of the muscle or tangentially in the muscle belly only? Can ptosis be avoided, with continued clinical success, by orienting the injection needle superolaterally in the region of the medial brow?

Surgical removal of the corrugator and procerus muscles is the ultimate treatment for functional glabellar frown lines. However, whether through a transpalpebral or forehead-brow approach, this represents a major operation, which may not be appealing to patients for management of glabellar frown lines alone. The most attractive noninvasive, transcutaneous management now appears to be by means of the intramuscular injection of botulinum toxin type A. Achieving effective results, while minimizing recurrence or attendant complications, depends on accurate understanding of the muscular anatomy and associated surface landmarks.

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REFERENCES