Title

The Direction of Optimal Skin Incisions Derived From Striae Distensae.

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The Direction of Optimal Skin Incisions Derived from Striae Distensae

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Background: In an effort to achieve inconspicuous scars, plastic surgeons try to place their incisions in established creases and folds of skin. Although well established in the face and abdomen, these folding lines are often disputable on other parts of the body. Striae distensae always develop perpendicular to lines of tension, and their direction can be used to determine optimal incision lines.
Methods: The authors examined photographs of 213 individuals with striae, and a composite diagram was created. This composite along with descriptions of Langer lines, Pinkus main folding lines, and Kraissl lines were compared with a clinical scar revision database and 276 images of incisions and scars from the Internet.
Results: Pinkus described the main folding lines in 1927 and Kraissl in 1951 recommended that incision lines be placed perpendicular to the direction of underlying muscles. Both references bear some similarities to what we noted in our composites. In comparison, Langer lines, although of historical interest, poorly predicted the direction of optimal skin incisions.
Conclusions: The optimal direction for surgical skin incisions should take into strong consideration patterns defined by nature's striae distensae, which always develop perpendicular to skin tension lines. Main folding lines can be used as guides when addressing or refining problem scars and similarly facilitate surgical planning of elective incisions, which may prevent problem scar formation for our patients. (*Plast. Reconstr. Surg.* 133: 00, 2014.)

Plastic surgeons are often tasked with correcting conspicuous scars resulting from prior operations. It is generally well considered that in many cases a suboptimal or inappropriate position or location of the planned skin incision contributes to the development of troublesome scar formation. Classically, surgeons planned their incision or excision directly over the intended target or relied on Langer's description of "cleavage lines" (Fig. 1)[1] when planning both incisional and excisional approaches.

In an effort to achieve minimal scar formation, surgical incisions are generally considered to be most appropriately designed in Pinkus' "main folding lines" (Fig. 2),[2] Kraissl's "anti-muscular lines" (Fig. 3),[3,4] and Borges' "relaxed skin tension lines."[5–7] These directions, although clearly and undisputedly identified in both facial and abdominal folds, are unfortunately often very challenging to determine in the younger patient, as these folds do not manifest until late. This is particularly true when dealing with skin distributions of both the upper and lower extremities and back. These folds do not manifest until late in most.

Striae distensae, a reflection of cellular, fibrillar, hormonal, and mechanical alterations,[8–10] are well-known cutaneous sequelae evident in a wide variety of physiologic and pathologic states.[11–16] Striae are like hypotrophic scars[9]: their collagen lattice has been ruptured under the influence of steroids and especially estrogens.[8,17,18] Their location and distribution tend not to correlate with classically defined relaxed skin tension lines (Fig. 4). We hypothesized that by cataloguing and describing patterns of striae distensae, these composite data might prove to be an effective guide in planning elective incisions.

PATIENTS AND METHODS

Institutional review board approval was obtained from the Markus Hospital in Frankfurt

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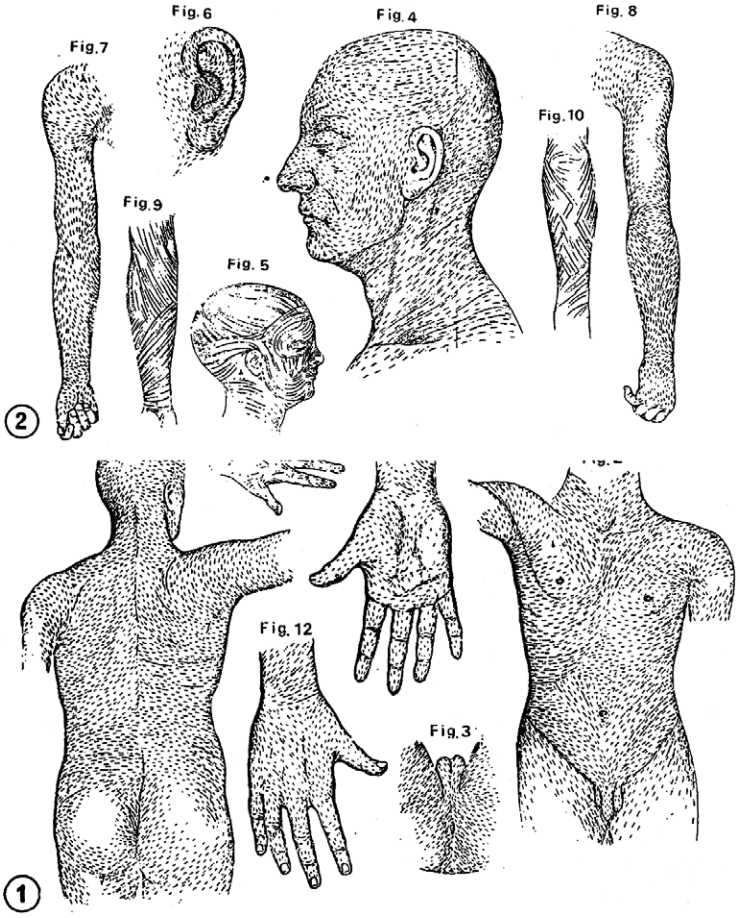

Fig. 1. Langer's "cleavage lines" run obliquely or perpendicular to the recommended "main folding lines" of the forehead, cheeks, lower abdomen, upper back, buttocks, and extremities. [Reprinted from Langer K. On the anatomy and physiology of the skin. I. The cleavability of the cutis. (Translated from Langer K. Zur Anatomie und Physiologie der Haut. I. Uber die Spaltbarkeit der Cutis. *Sitzungsbericht der Mathematisch-naturwissenschaftlichen Classe der Kaiserlichen Academie der Wissenschaften* 1861; 44;19.) *Br J Plast Surg*. 1978;31:3–8.]

am Main, Germany. Photographs of 213 individuals with established striae or stretch marks were catalogued (78 clinical patients and 135 Internet images). Our plastic surgery database of images consisted of all patients diagnosed within the past 50 years with striae that presented in adolescents, in women during or after pregnancy, in patients as a result of Cushing disease or steroid abuse
F5 (Fig. 5), and in cases of "linear focal elastosis."[19] An Internet Google search for suitable images from a key word search of "striae" and "stretch marks" was similarly catalogued and evaluated, resulting in 135 pictures.

The direction and location of all striae were
F6 noted (Fig. 6), defined, and used to create a series
F7 of composite diagrams (Fig. 7). These composites, and those defined by Pinkus[2] and Kraissl,[4] were then compared with a scar revision database of hundreds of patients from the Department of Plastic Surgery at the Markus Hospital in Frankfurt am Main, Germany, and 276 images of surgical incisions and scars derived from the Internet. Incision position and scar quality were comprehensively reviewed and critiqued by three experienced reviewers and recorded as either respecting or contradicting the composite.

RESULTS

Regardless of their cause, all striae demonstrate a similar clinical appearance and orientation in both male and female skin, and orient parallel or slightly oblique to the direction of muscular pull. Furthermore, the direction of the

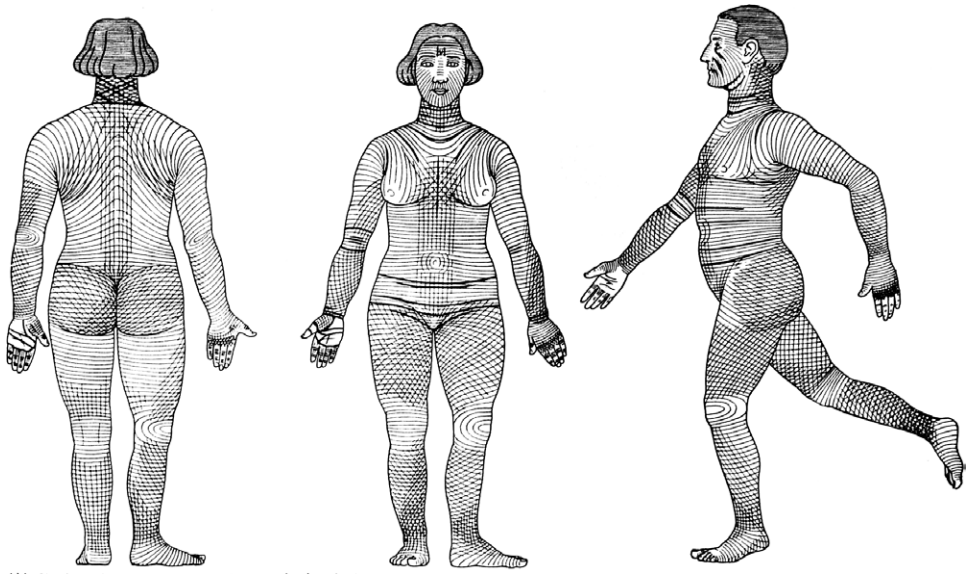

Fig. 2. Pinkus' main folding lines of the skin facilitate optimal incision planning. However, the shear number of lines and intersecting paths can prove rather disorienting and confusing. (Reprinted from Pinkus F. Die Faltung der Haut. In: Pinkus F, ed. *Die normale Anatomie der Haut. Jadassohn's Handbuch der Haut und Geschlechtskrankheiten*. Vol. 1. Berlin: Springer; 1927:4–76.)

lamellae in patients with "linear ichthyosis"[20] is the same as the skin's main folding lines across the entire body. These phenomena were identified in individuals of all ages and races, as observed in our database.

F8 Striae-derived tension lines (Figs. 7 and 8) correlated well with the direction and description of the Kraissl lines on the shoulder, chest, abdomen, and extremities, but not on the areas of the mid upper and lower back and buttocks, where they run parallel to the underlying muscle fibers of the trapezius and gluteus maximus muscles, respectively. Langer's lines of the upper back, abdomen, chest, anterior thigh, knee, and lower leg were consistent with those observed in striae-derived tension lines, and conflicting when matched to areas of the lower abdomen, back, buttocks, posterior thigh, and foot.

Striae were not identified in all regions of the body, with notable exceptions being the scalp and feet. The elongation patterns and the direction of striae over the ventral aspect of the lower leg, retrieved from the folding lines of elderly patients and those with linear ichthyosis,[20] were consistent with the direction of muscular pull. In children and adolescents, the main skin folding lines in the face, neck, hand, and foot can be identified by moving the individuals' facial muscles or limbs.

Direction of Striae and Optimal Incisions

Following the striae-derived skin tension or main folding lines (Fig. 7), we propose for

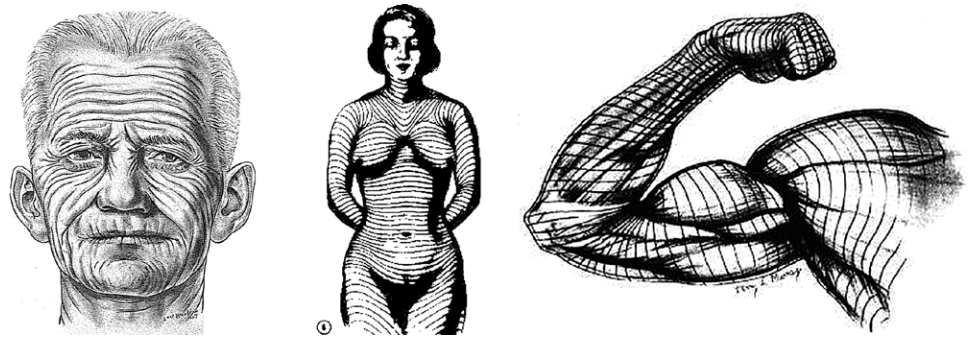

Fig. 3. The Kraissl lines run "perpendicular to the direction of the underlying musculature." The facial fold lines show long accepted incision lines advocated for use in facial surgery. (Reprinted from Borges AF, Alexander JE. Relaxed skin tension lines, Z-plasties on scars, and fusiform excision of lesions. *Br J Plast Surg*. 1962;15:242–254.)

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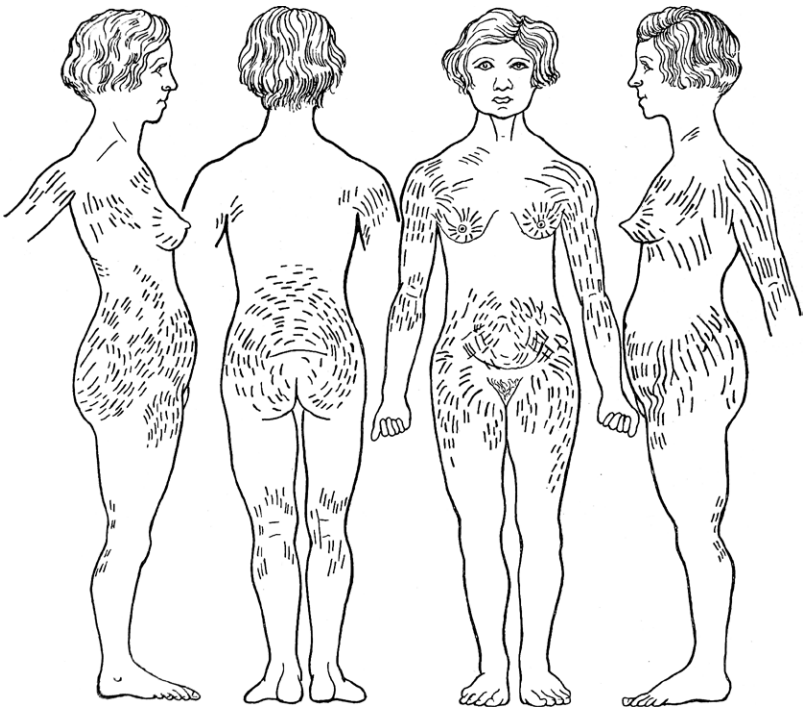

Fig. 4. Striae gravidarum by Pinkus. (Reprinted from Pinkus F. Die Faltung der Haut. In: Pinkus F, ed. *Die normale Anatomie der Haut. Jadassohn's Handbuch der Haut und Geschlechtskrankheiten*. Vol. 1. Berlin: Springer; 1927:4–76.)

common operations in general and orthopedic surgery incisions as indicated in Figure 8.

Face and Neck

The regions of the face and neck can be considered rather unique as, despite their propensity toward the development of disfiguring and problematic scar formation, these areas generally present with well-established patterns for judicious placement of surgical incisions (Fig. 3, *left*). The well-recognized patterns of skin folds and wrinkles[21] determine the logical direction for surgical incisions or fusiform skin excisions. In young patients, the wrinkle and facial fold patterns observed in parents or grandparents can serve as a guide for optimal directions (Fig. 3) and can establish patterns identified in classic textbook descriptions of surgical incisions of the face.[3–7]

Neck folds present transversely and accentuate in the mature face. Incision lines on the neck should always run horizontally and preferably be designed inside already existing horizontal neck folds. The skin incision for tracheotomies,[22] and access to the cervical disks, should preferably be designed horizontally. Thyroidectomy incisions should be designed whenever practical, higher up in a horizontal neck fold, and preferably not over the jugulum,[23] where hypertrophic scars have a higher tendency to present.

Shoulder and Axilla

Striae observed in bodybuilders and patients with linear focal elastosis or Cushing syndrome tend to orient horizontally over the pectoral and deltoid muscles (Figs. 5 and 6). Incisions made parallel to these striae and those oriented parallel to the clavicle as with open reduction and fixation of fractures may often result in wide and hypertrophic scars. As such, incisions across the shoulder joint and deltoid muscle should be avoided when possible in favor of an axillary incision extended vertically to the clavicle or scapula.

Arm and Hand

With respect to the upper extremities, striae do not tend to develop straight or axially, but rather obliquely from the axilla to the inner elbow (Fig. 9). The lines of tension lines of the upper arm and forearm are not perpendicular to the direction of muscle pull[4] (e.g., circumferentially) (Fig. 3) but rather are obliquely oriented and proceed over the joints in horizontal skin folds. Upper arm longitudinal and vertical incisions placed in young patients, such as those often used to expose a fracture, should ideally be avoided (Fig. 9) and replaced by oblique half-circumferential incisions. F9

When planning an incision in the extremities, one must consider the direction of the underlying

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Fig. 5. Extreme striae distensae in a 14-year-old boy treated with a protracted course of steroids for encephalitis. (Reprinted from Rotsztejn H, Juchniewicz B, Nadolski M, Wendorff J, Kamer B. The unusually large striae distensae all over the body. *Adv Med Sci*. 2010;55:343–345.)

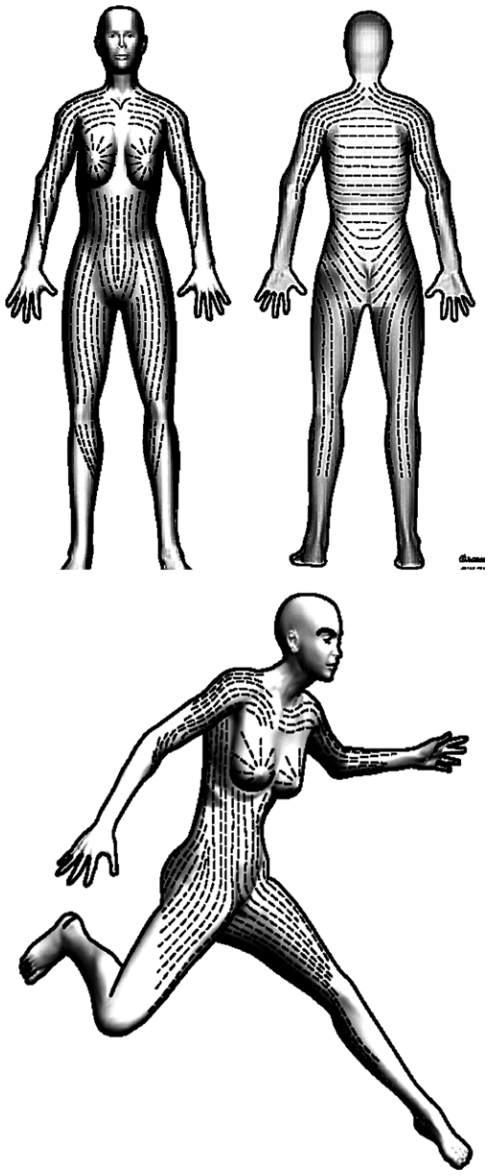

Fig. 6. Composites of striae lines derived from a database of 213 photographs.

neurovascular bundles, which generally run axially. On the forearm, the main folding lines appear different in pronation and supination but are always oblique[24] (Fig. 9). On the palmar aspect of the hand, incisions should be made inside natural creases. On the dorsum of the hand, horizontal incisions will fall into the main folding lines. Vertical incisions should be hidden on the ulnar thenar or on non–pinch-oriented aspects of the fingers.

Chest and Breast

Striae over the upper chest develop mainly laterally and in a horizontal direction over the pectoral muscles, traversing farther horizontally over the deltoid muscle to the front of a horizontally stretched arm (Figs. 6 and 9). The resultant lines on the chest are oblique and become more circular as they progress toward the arm. It appears that gravitational forces and mammary gland movement modify this pattern. Women who sleep positioned on their side for many years likely accentuate main folding lines in their décolleté, which originate at the clavicles and transition V-shaped toward the midsternum (Fig. 7).

When designing a sternotomy incision in adolescents, it is advisable when appropriate to plan the median skin incision as caudally as possible (e.g., spare an incision over the manubrium sterni and preferably undermine the skin in the direction of the jugulum). In thoracic, cardiac, and pulmonary operations, hypertrophic scarring may potentially be prevented or minimized, particularly in children and young women, by designing a wide, half-circumferential, horizontal incision in the submammary fold (Fig. 10). When clamshell exposures are required, bluntly raising

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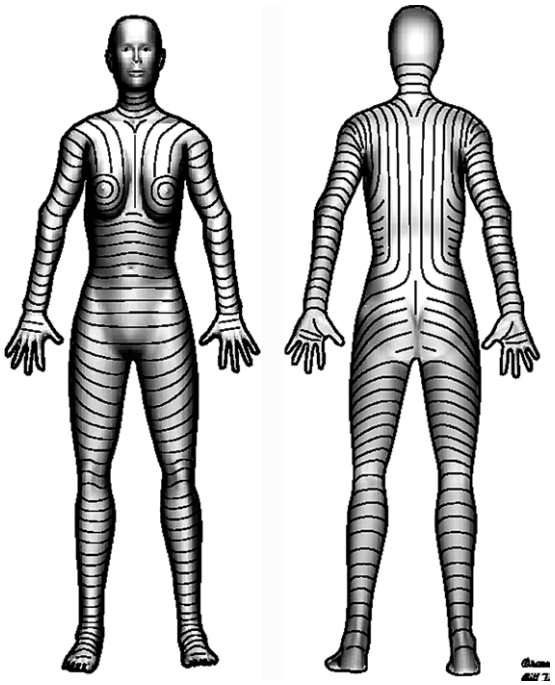

Fig. 7. Main folding lines running perpendicularly to the striae lines. These are derived from the striae composite depictions (Fig. 6).

both breasts to reach the fourth or fifth intercostal space or even the jugulum can afford a preferential path.

On the breast, striae radiate from the areola outward (Fig. 10); as a result, optimal incisions will run circumferentially. In augmentation mammoplasty, they are routinely developed in a periareolar manner[25] or through a horizontal axillary or submammary incision.

Lateral incisions through the rib cage are always performed slightly oblique and oriented along the pattern established by the contour of the ribs (Fig. 7). In young female patients, they should ideally be hidden anteriorly in the prospective submammary fold. Every effort to maintain the integrity of the latissimus should be respected.

Abdomen

The abdominal skin prominently demonstrates how striae distensae develop perpendicular to the skin folding lines. Therefore, horizontal skin incisions should be designed accordingly (Fig. 7). It has long been advocated[26] that wide transverse incisions along the

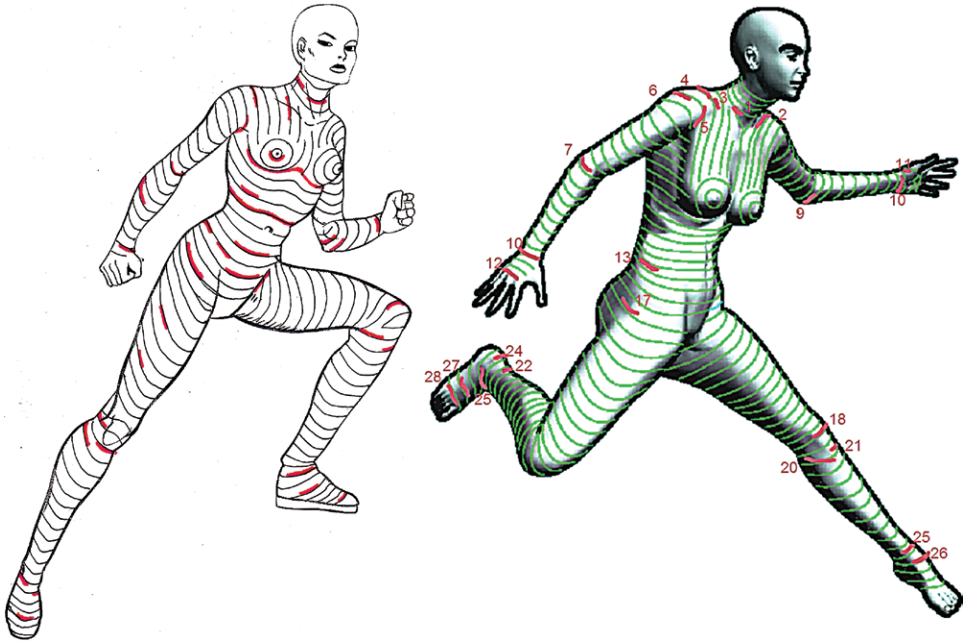

Fig. 8. (*Left*) Recommended skin incisions for common surgical procedures in adolescents and female patients. (*Right*) Recommended orthopedic incisions to access joints in adolescents: *1*, sternocleidomastoid muscle; *2*, sternoclavicular joint; *3*, clavicle fracture; *4*, acromioclavicular joint; *5*, ventral shoulder joint; *6*, rotator cuff; *7*, olecranon and radial epicondyle; *8*, radial head; *9*, ulnar epicondyle; *10*, wrist; *11*, carpometacarpal joints; *12*, phalangeal exposure; *13*, anterior iliac crest; *14*, thoracic vertebrae; *15*, posterior iliac crest; *16*, lumbar vertebrae and disks; *17*, greater trochanter; *18*, patella; *19*, knee joint; *20*, tibial head; *21*, tibial tubercle; *22*, Achilles tendon; *23*, ankle joint and calcaneus; *24*, dorsal ankle joint; *25*, ventral ankle joint; *26*, tarsal bones; *27*, metatarsals; *28*, metatarsophalangeal joints.

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Fig. 9. Recommended surgical incisions must respect and consider the direction of cutaneous nerves and underlying neurovascular bundles. (*Above*) Hypertrophic scar after repair of clavicular fracture. Note the unfavorable incisional design perpendicular to the main folding lines. (*Below*) Striae distensae over the inner arm of a Cushing syndrome patient.

natural folds of the upper abdomen provide excellent exposure to all intraperitoneal organs and have been noted to heal well and with significantly fewer complications than vertical incisions directed through the linea alba. General surgeons, however, continue to favor the traditional vertical midline incision in the overwhelming majority of their patients despite a risk of midline hernia occurrence of up to 17 percent in elderly, obese patients with multiple morbidities.[27] Small vertical scars can often easily be corrected by a horizontal excision (Fig. 11). F11

Back and Buttock

A simple provocative experiment of approximating the scapulae and extending the arms will reveal many folding lines in the mature individual. This generally vertical pattern of folds may have an exception in young women where scars can be hidden beneath a horizontal bra or bikini strap. On the back and over the buttocks, orthopedic skin incisions in hip joint surgery in children and adolescents should follow an oblique direction (e.g., perpendicular to the striae) (Fig. 12) but F12 exceptionally parallel to the fibers of the gluteus maximus muscle (Fig. 8).

Leg and Foot

When considering the inner and outer thigh regions, oblique incisions should follow the main folding lines readily observed in mature patients (Fig. 7) or those with striae (Fig. 12). Above the knee, horizontal and half-circular folding lines surround the patella (Fig. 8). As opposed to the commonly observed vertical incision directly over the knee (Fig. 13), these medial and lateral curvi- F13 linear folds are preferred whenever feasible.

The skin folds on the lower extremities are analogous to those observed in the upper limbs. Therefore, oblique incisions from medial proximal to lateral distal over the calf are proposed, whereas incisions over the fibula should be made obliquely from proximal posterior to distal

Fig. 10. (*Left*) Perfect scar after "clamshell incision" for lung transplantation in the folding lines. (*Right*) Radial striae gravidarum on the breasts.

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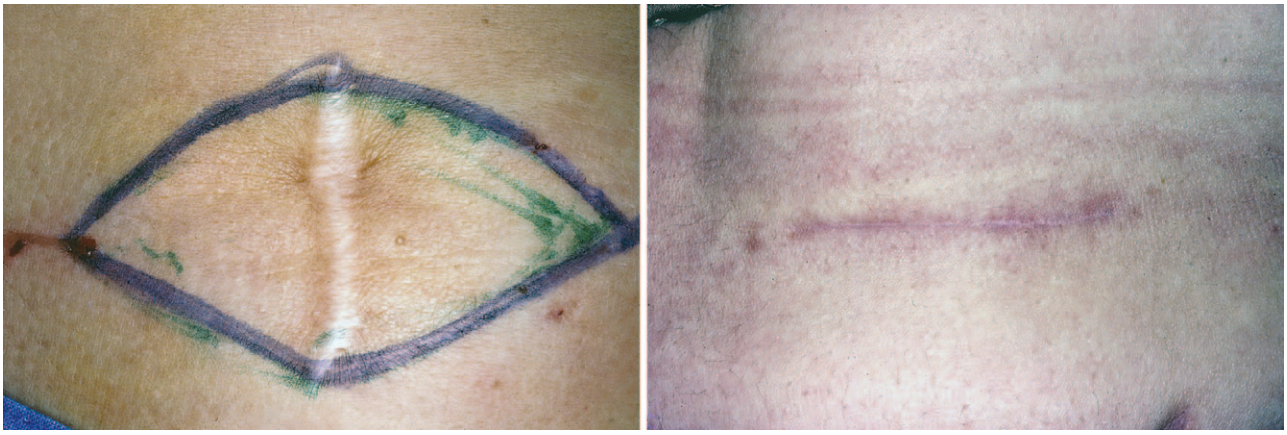

Fig. 11. Horizontal excision of a hypertrophic vertical scar after cholecystectomy, converting an unfavorable scar direction to a favorable one.

anterior, with attention to protect the underlying peroneal nerve (Fig. 8).

In our review, we did not identify distinct patterns of striae on the feet. As a result, one generally has to rely on the main folding lines, which are evident during foot movement, rather than on less well-defined Langer lines.[28] Over the back of the foot, Z- or S-shaped incisions will heal better than straight vertical ones.

Hypertrophic scarring can often complicate vertical scars positioned over a ruptured and repaired Achilles tendon (Fig. 13). Therefore, we suggest the judicious application of rather short horizontal incisions whenever possible and, if necessary, vertical elongations hidden behind the ankles. As is always the case in surgery, the position of critical structures and neurovascular bundles must be respected and considered in design. Longer incisions may be angled across the natural skin folds.

DISCUSSION

The most appropriate planning and positioning of a surgical incision is generally based on multiple logistic considerations and practicalities. The approach should prove to be efficient, effective, and, most importantly, safe. Over the past century, numerous guidelines have been introduced and advocated toward this end. In fact, a brief literature search of the topic revealed at least 38 different named guidelines.[6,29–34] Most notable are those of Pinkus, who in 1927 described "main folding lines,"[2] and Kraissl, who described "incisions perpendicular to muscle action" in 1951.[4,5] AQ2

It is important to recognize that Langer, an anatomy professor, derived his "lines" from cadaveric study, in rigor mortis.[1,28,29] Langer lines often run obliquely or even perpendicular to most of the skin folds. Perhaps most telling is the fact that Langer lines extend vertically across the antecubital region, wrist, thigh, and tibial region. It is likely

Fig. 12. (*Left*) Striae distensae over the buttocks of an adolescent. Note that their direction runs parallel to the underlying muscle fibers of the gluteus. (*Right*) Striae distensae over the inner thigh of a Cushing syndrome patient.

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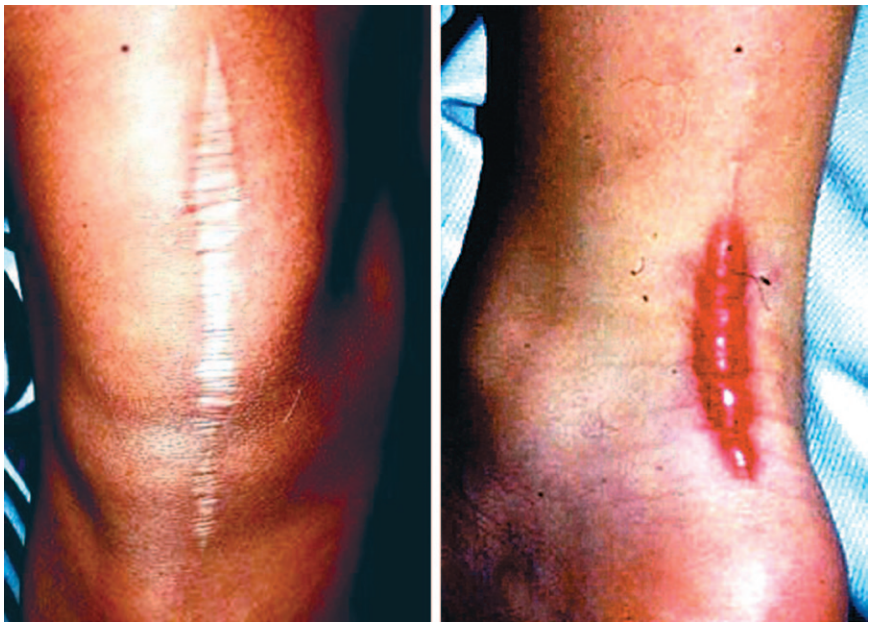

Fig. 13. (*Left*) Wide vertical scar after open knee synovectomy. Consider instead a medial or lateral curvilinear approach in young patients. (*Right*) Hypertrophic scar after Achilles tendon lengthening, a horizontal approach transitioning retromalleolar might afford a more favorable outcome.

that Kocher's endorsement in 1892[23] to use these lines as a guideline to surgical incision placement was ill founded and, although often quoted in surgical textbooks, they were likely never intended to be used as such.

Fig. 14. Z-plasties after correction of a pterygium colli. The horizontal scars parallel to the main folding lines of the neck heal normally. The vertical scars that were designed perpendicular to the main folding lines are healing under tension and demonstrate hypertrophy.

As early as 1927, dermatologist Felix Pinkus[2] was perhaps the first to question the application of the Langer lines as a guide for skin incisions. He subsequently went on to describe the main folding lines of the skin (Fig. 2) but did not advocate their use in defining the ideal direction for elective incisions. Interestingly, Pinkus also described and illustrated the location of striae; however, he did not relate them to skin incisions (Fig. 4). As a dermatologist, it is unlikely that his publication of main folding lines[2] would reach the surgical community.

In 1950, Cornelius Kraissl[3,4] proposed distinct lines usually oriented perpendicular to the action of the underlying musculature (Fig. 3) by demonstrating grossly and histologically that adherent connective tissue bands run from the skin to the underlying fascia, perpendicular to the long axis of the muscles, and especially over joints such as the wrist and knee. Several years later, in 1962, Alberto Borges[5,6] described "relaxed skin tension lines" of the face, and in 1984 went on to describe them on the body[7] as well. These lines followed furrows produced by pinching the skin in different directions, a technique suggested previously by both Pinkus[2] and Kraissl.[3,4] However, this "pinching" technique can be difficult to perform in locations such as the thick skin of the youthful back. Variability also complicates this technique, as is evident when

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applied to the extremities, where pinching in several directions can form conflicting patterns of furrows dependent on the direction of force and supinate and pronate positioning.[25] Courtiss in 1963[32] and Barile in 1976[33] essentially copied the article and illustrations of Kraissl,[3,4] recommending like Borges, that the Kraissl line be followed for the rest of the body.

CONCLUSIONS

Striae distensae result and manifest as perpendicular reflections of musculoskeletal defined lines of tension. As such, they can be considered to follow natural antitension lines of the skin.[34] Applying these observations can facilitate surgical incision planning based on the direction of the striae distensae, which develop perpendicular to the optimal skin incision lines.

The composite diagrams derived from our study of the direction of striae distensae (Fig. 7) are meant to serve only as guidelines. Planning a surgical incision requires considering many critical anatomical and logistical elements, all designed to afford safe and efficient mechanical exposure to the target of our efforts. Preserving deep and surrounding structures while taking into account the direction of the underlying muscles, critical neurovascular structures, and optimizing vascularity to healing structures is essential. Appreciating functional and aesthetic design in this equation will likely result in what we believe will be an optimal result for our patients (Fig. 9).

In young and female patients, we advocate and prefer incisions that, whenever possible, include staggered depth progression in an effort to minimize anatomical derangements and direct indiscriminate through-and-through approaches that predispose to hernia formation.[27] Ultimate functional results and potential future reconstructive options are optimized when anatomical disregard is avoided. The convincing proof are Z-plasties,[5,6] where those scars following the main tension/folding lines are minimal, whereas those perpendicular to the main tension lines often heal with hypertrophy in young patients (Fig. 14). F14

Small incisions for minimally invasive surgery should similarly follow these patterns of fold lines. The normal skin folds should serve as the primary guide for the direction of small fusiform skin excisions and all longer incisions in selected younger patients. The importance of minimizing tension and trauma to the incision cannot be overstated. Minor extensions can go a long way toward optimizing exposure and minimizing traction and crush injury to wound edges and surrounding tissues.

The term "relaxed skin tension lines"[5–7] is in our opinion a rather confusing virtual expression, whereas the term "main folding lines"[2] appears simpler and easier to understand. The simplest rule for making incisions in the most favorable direction is to follow natural folding lines: "Proper incisions come together naturally and improper ones tend to gape."[24]

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AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES

AQ1—Affiliation correct for all authors? If not, please specify each author's affiliation at the time the work was performed.

AQ2—There were two reference 29's and two reference 30's on list; references were renumbered accordingly and all are cited here ("6,29-34"). Correct as edited? If not, please cite references 29 through 34 in the correct place in the text, and renumber throughout as needed so that refs are cited in numerical order, per Journal style.

AQ3—Ref 10: Please update publication status, if possible.

AQ4—Ref 23: Please provide chapter title, and chapter end page number.