The Etiologies of Chest Wall and Breast Asymmetry and Improvement in Breast Augmentation

Caroline A. Glicksman, MD[a,b,*], Sarah E. Ferenz[c]

KEYWORDS

• Breast augmentation • Congenital deformities of the chest wall • Highly cohesive breast implants • Biodimentional planning • 3-dimensional imaging • Shaped breast implants

KEY POINTS

- Patients presenting for correction of breast and chest wall asymmetries may have undergone numerous thoracic procedures in early childhood and some may have suffered profound psychosocial effects.
- Care must be taken to evaluate these patients using objective criteria and biodimentional principles. Long-lasting correction of asymmetry can be obtained when patients are not oversized, and care is taken to avoid visibility, palpability, and malposition problems.
- Complex congenital syndromes often require a more comprehensive preoperative work-up, as well as a detailed history of any previous thoracic or breast procedures.
- Patient education needs to be comprehensive, and patients should be encouraged to have realistic expectations and accept what can and cannot be corrected.
- Shaped highly cohesive breast implants offer plastic surgeons more possibilities and precision by fine-tuning the gel distribution and specific volume required to correct the hypoplastic elements.

OVERVIEW

Today, most children born with mild to severe congenital deformities of the chest survive well into adulthood. Rarely, deep thoracic wall depression leads to displacement or compression of the heart and lungs, and thoracoplasty is indicated. Most affected children survive into adolescence, and the indications for correction of breast and chest wall defects are based on psychological difficulties and issues of self-esteem. As technical skills improved over the last half a century, minimally invasive procedures such as those of Nuss (minimally invasive repair of pectus excavatum) and Ravitch gained popularity, and common chest wall defects are now routinely treated.[1] The spectrum of chest wall abnormalities varies, from complex congenital musculoskeletal deformities to the more common defects like anterior thoracic hypoplasia. The correction of chest wall and breast deformities with breast implants dates back to the early 1970s, and although originally reserved for mild chest wall and breast asymmetry, the availability of shaped highly cohesive breast implants that allow a surgeon to select a specific width, projection, and height independently, may provide a single-stage option to correct more complex deformities.

[a] Glicksman Plastic Surgery, Sea Girt, NJ, USA; [b] Department of Surgery, Jersey Shore University Medical Center, Neptune, NJ, USA; [c] Department of Biology, Cornell University, Ithaca, NY 14853, USA
* Corresponding author. Glicksman Plastic Surgery, Sea Girt, NJ.
E-mail address: docmomcag@aol.com

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EMBRYOLOGY OF CHEST WALL AND BREAST DEVELOPMENT

The development of the musculoskeletal system of the trunk is a multistep process that occurs between the fourth and eighth weeks of development. The paraxial mesoderm divides into 2 subpopulations, the dorsolateral subpopulation (dermomyotome) and the ventromedial subpopulation (sclerotome). Myoblasts within the dermomyotome differentiate into the skeletal musculature, while the sclerotome develops into the vertebrae and ribs. The sternum is derived from somatic mesoderm. The ribs and sternum fuse in the midline in the sixth week of development, and fusion occurs in a cranial–caudal direction completed by the tenth week. Failure to fuse leads to a cleft sternum. The manubrium is formed by primordia between the developing clavicles.[2] The breasts develop during the sixth week of gestation from ectodermal cells along the milk line, which extends from the axilla to the groin. The upper and lower parts of these ridges atrophy, with only the middle or pectoral ridges developing into breast tissue.[3] The exact etiology of chest wall and sternum deformities remains controversial. Causes include overgrowth of costal cartilages, sternal twisting, and a relative weakening of the costal cartilages.[4] The growth and development of the sternum are influenced by both genetic factors and biomechanical factors. Although no specific gene locus has been yet identified for conditions like Poland syndrome and cleft sternum, there is a definite mutation associated with some chest wall and breast deformities. Chest wall and breast deformities can be classified as either monogenic, disruption sequences, isolated chest wall deformities, or acquired chest and breast deformities (**Table 1**).

HISTORICAL MANAGEMENT

Early reconstructive efforts to correct chest wall deformities were primarily performed for improvement in cardiopulmonary function. Aesthetic considerations were usually reserved until patients reached puberty and maximum sternal development. Surgical corrections of chest wall defects were usually delegated to pediatric surgeons, and early invasive procedures have evolved toward more minimally invasive techniques. The 2 most common procedures used today are the Modified Ravitch procedure (transverse sternal osteotomy with subperichondrial costal cartilage resection) and the Nuss procedure (minimally invasive repair of pectus excavatum).[5] With advances in local muscle flaps, contour defects of the chest wall and hypoplastic

Table 1
Etiology of most common chest wall deformities and resultant end organ failure

Origin of Deformity	Anatomic Site	Disorder
Monogenic syndromes	Ventral body wall–rib Sternum Breast Spine	Marfan syndrome Noonan syndrome
Disruption sequences	Thoracic musculature Ventral body wall- rib Breast Spine	Poland syndrome Moebius syndrome
Genetic associations (chromosome aberrations)	Ventral body wall–rib Sternum	PHACE (posterior fossa brain malformations) Cantrell pentalogy Asphyxiating thoracic dystrophy (Jeune syndrome) Cleft sternum
Isolated chest wall deformities	Breast Ventral body wall–rib Sternum Spine	Pectus excavatum Pectus carinatum Thoracic hypoplasia Supranumerary breasts Congenital absence breast Tuberous breast Constricted base breast Gynecomastia
Acquired	Ventral body wall Thoracic musculature Breast	Tetralogy of Fallot

or absent musculature were replaced with local flaps, including the latissimus dorsi flap. Beginning as early as the 1970s, custom-made silicone implants were used requiring the fabrication of a chest wall mold or moulage. It is interesting to note that early silicone rubber chest wall prostheses were firm, having the consistency of muscle tissue. Custom implants were often inserted deep to the serratus, occasionally with a second implant stacked on top to augment the breast. Early custom implants were most often shaped and textured. Several manufacturers supplied custom implants to plastic surgeons until the late 1990s. Inamed (Allergan-Actavis: Irvine, CA, USA and Rockaway, NJ, USA) stopped importing custom implants in 1997, as did Sientra (Santa Barbara, CA, USA) between 2010 and 2011, and Silimed (Rio de Janeiro, Brazil) ceased production of custom silicone implants in 2014. Adjustable saline implants played a significant role in the treatment of chest and breast asymmetry due to the ability to add more volume to the affected hypoplastic chest and breast. Round silicone gel implants have grown in popularity and have largely replaced saline implants, which have high rates of visibility and palpability. The development of shaped highly cohesive gel breast implants has further steered breast augmentation surgeons away from the older volumetric management of asymmetries toward that of shaping the chest and breast with biodimentional planning. Anatomic implants provide not only the increase in volume required to correct the hypoplastic elements, but because surgeons can select the implant by height, base width, and projection, the ability to correct individual chest wall anomalies.[6]

ACQUIRED CHEST WALL DEFORMITIES

Although rare, breast and chest wall asymmetry may be the result of pediatric thoracic surgery. Breast bud injuries can result from chest tube placement as well as thoracotomy procedures. Open thoracotomies can produce significant musculoskeletal morbidity, including atrophy of the serratus anterior muscle and pectoralis due to surgical incisions (**Fig. 1**).[7] Patients may also present to the office after multiple attempts to correct a pectus excavatum or similar sternal deformity, and may have already undergone a breast augmentation with revisions. These cases are certainly more difficult to approach, and patients should be informed that some deformities produced by

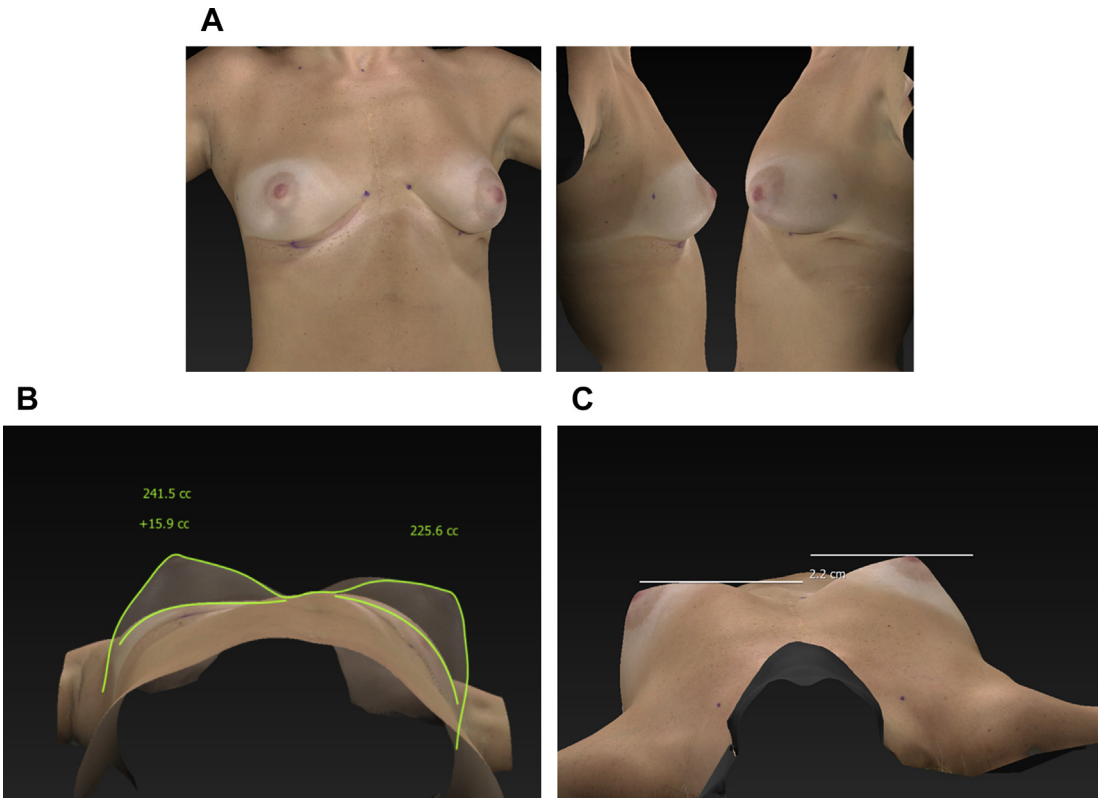

Fig. 1. (*A–C*) 23-year old with history of tetralogy of Fallot. Vectra 3-dimensional image demonstrates degree of chest wall deformity in a patient who underwent multiple cardiac surgeries within the first 5 years of life.

detachment of muscles, scarring, or thinning of overlying soft tissues may be uncorrectable (**Fig. 2**).

PSYCHOSOCIAL IMPLICATIONS

For young women with isolated chest and breast deformities, concerns about body image often drive them into a plastic surgeon's office. For those patients with genetic mutations that affect multiple organ systems, their physicians and family often underestimate the significance of their deformity. Most children affected with chest wall deformities begin to recognize that they are different from other children around the age of 4 to 6 years. Teasing and peer ridicule continue into adolescence. Clothing often hides breast deformities, but self-esteem issues worsen through the teenage years.[8] The psychological and social impact of breast asymmetry has been well documented. Poor body image and impaired psychosocial functioning increase with age in patients who have not had surgery.[9] Just as a young woman is establishing an independent identity, going off to college, or beginning sexual relationships, she must also deal with the distress associated with her deformity. Her physical condition can deeply upset her ability to do all of those things. The effect on quality of life, self-esteem, and psychological well-being advocates early intervention for these patients.

PATIENT ASSESSMENT AND PREOPERATIVE PLANNING

Chest wall and breast asymmetries can vary, from significant unilateral defects involving the sternum, ribs, muscle, and breast, to very subtle asymmetries that are difficult to detect and quantify.[10] Technological advances available today increase a plastic surgeon's ability to evaluate patients with chest and breast asymmetry. For patients with more complex monogenic and chromosomal aberrations, chest computed tomography (CT) may be useful for thoracic surgeons and plastic surgeons to establish a proper preoperative plan. Computerized algorithms have been developed to facilitate quicker and more accurate diagnosis of the defects.[11] CT images may include axial images and 3-dimensional CT reconstruction. If available, these studies can be valuable in the preoperative planning for breast augmentation (**Fig. 3**).

For several years, the option of in-office 3-dimensional imaging has provided plastic surgeons the ability to generate reproducible and clinically valid data for studying breast volume, chest contour, and asymmetries.[12] In-office 3-dimensional imaging can be integrated into the preoperative consultation, improving physician–patient communication and the management of patient expectations. Simulations can illustrate possible outcomes using selected implants and also demonstrate what may be a correctable or uncorrectable deformity. Simulations can also streamline the implant selection process, reducing the number of implants ordered and possibly the need for multiple sizers (**Fig. 4**).

CORRECTION OF CHEST WALL AND BREAST ASYMMETRIES WITH SHAPED HIGHLY COHESIVE GEL IMPLANTS

Shaped highly cohesive breast implants provide a greater degree of individualization and choices for

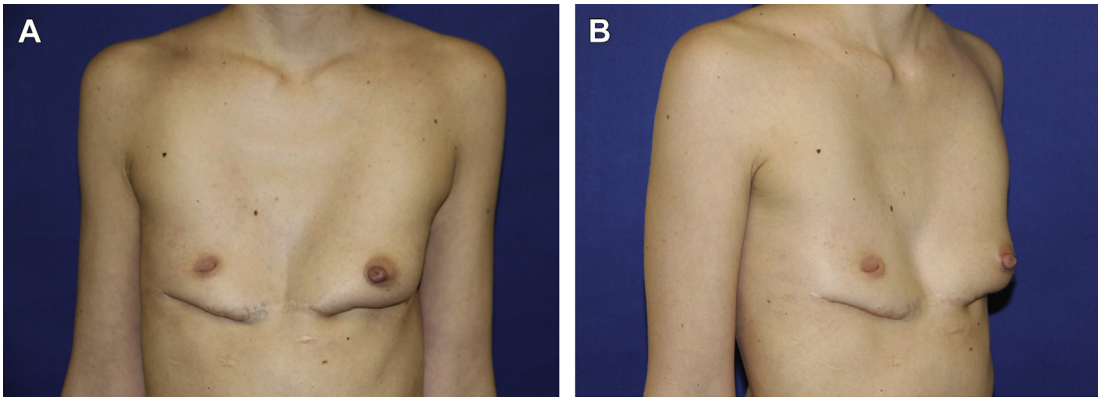

Fig. 2. (*A, B*) 31-year-old with Marfan syndrome. Minimally invasive pectus repair at age 10 years, revision at 18 years, and 2 scoliosis surgeries. First breast augmentation at age 18 with subglandular saline implants. Developed inferior malposition and synmastia. Revision with pocket change to submuscular saline at age 20 followed by another revision for recurrent malposition. Third revision with bilateral inferior capsulorrhaphy age 21. She subsequently developed recurrent synmastia and malposition and presents 10 years after explantation.

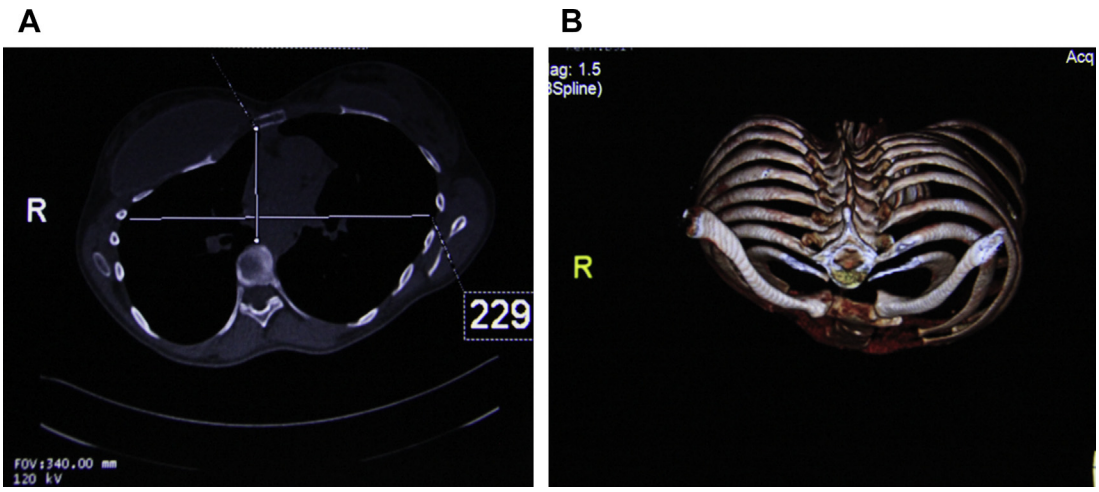

Fig. 3. (*A, B*) 22-year old with Marfan syndrome. Preoperative CT scan demonstrates severe chest wall deformity and presence of 2 asymmetric round gel implants. 3-dimensional CT reconstruction demonstrates significant chest wall asymmetry.

each patient. The ability to select an implant based on the base width, height, and projection as independent variables makes these implants especially valuable in the correction of chest wall and breast deformities. Detailed preoperative evaluation of thoracic and glandular asymmetries with objective measurements will provide the surgeon and patient with a small range of possible implant choices. Additional considerations include the assessment of the patient's soft tissue coverage, each breast type (tight, average, or loose-fatty), and patient desires. All of these parameters will contribute to the final implant selection.

Tissue-Based Planning

Tissue-based planning in breast augmentation has been well described and is critical when using shaped highly cohesive gel breast implants to correct chest wall and breast deformities.[13] Implant selection begins with determining the base width. This may be a bit more challenging in patients with chest wall deformities and asymmetry; however, the principles should be respected to avoid implant palpability and visibility. Soft tissue coverage is critical with all implants, as even the most highly cohesive implants available on the US market may be visible and palpable if oversized. The tissue type of the breast helps to define the projection of the device and may vary between breasts. Implant projection should be determined considering the need to correct asymmetry in both volume and shape, while respecting the breast fill, skin elasticity, and stretch. The sternal notch-to-nipple distance will help determine the height of the selected device. Here too, the desire to correct chest wall deformities needs to be balanced with the shape of the chest, which may vary between the right and left sides. The key measurements used in the selection of a shaped breast implant should be determined individually for each breast (**Fig. 5**). the authors attempt to correct the smaller breast or hypoplastic chest deformity to its optimal fill, and select a slightly smaller implant for the larger breast or chest wall. Oversizing a breast implant to correct a chest wall deformity or breast asymmetry will not produce a long-term stable outcome and may contribute to higher revision rates.

Techniques for Correction

It is recommended to use an inframmamary incision for the placement of a highly cohesive gel implant.[14] The planned incision should be well hidden in the new inframmary fold (IMF), which often needs to be adjusted. Lowering of the fold may help to achieve an optimal ratio between the base width (BW) and volume of the selected implant, and the new nipple-to-fold distance on stretch. The existing nipple-to-fold distance in patients with a chest wall deformity or breast asymmetry will likely differ between the 2 breasts. Ideally, although the location of the IMF on the chest may differ between the 2 sides, the final nipple-to-fold distance should not. Lowering 1 IMF beyond the recommended nipple-to-fold to BW ratio in an attempt to match the contralateral breast may result in an implant becoming inferiorly displaced over time, creating an upward pointing nipple-areolar complex (**Figs. 6** and **7**).

Whenever possible, the authors plan on placing the shaped implants in the dual-plane subpectoral pocket. This provides for optimal soft tissue

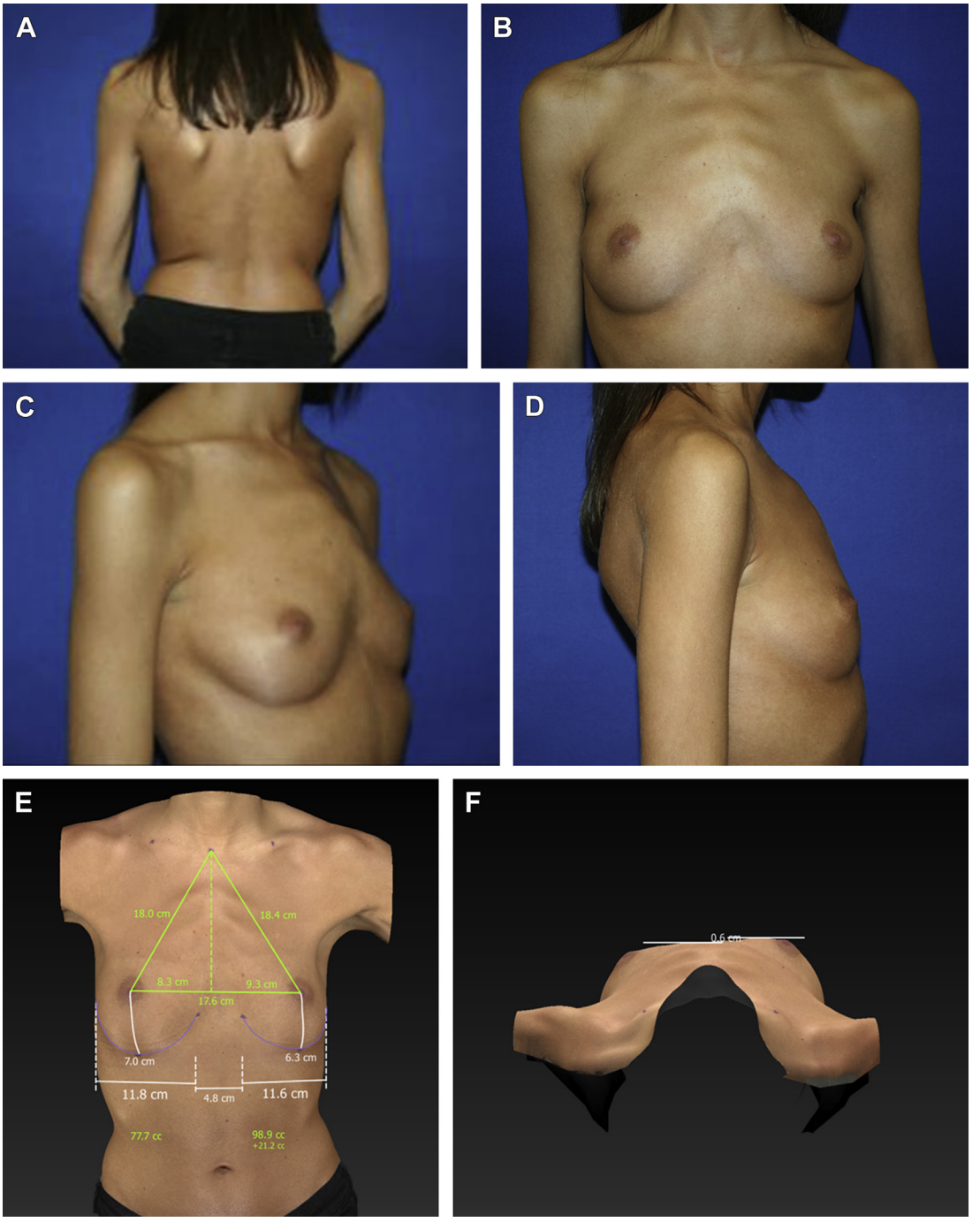

Fig. 4. (*A–D*) Standard photography documents the degree of chest wall and breast deformity in 30-year-old patient with Nail-Patella syndrome. (*E, F*) Preoperative 3-dimensional simulation can provide more detailed information on degree of breast asymmetry and location of chest wall defects.

coverage, especially in patients with hypoplastic breast tissue. A minimum incision length should be planned so as not to damage the implant during insertion. It has been well documented that pocket dissection and preparation for the implant should be dry and produce a hand-in-glove fit with the selected device. Intraoperative sizers can be avoided in most straightforward

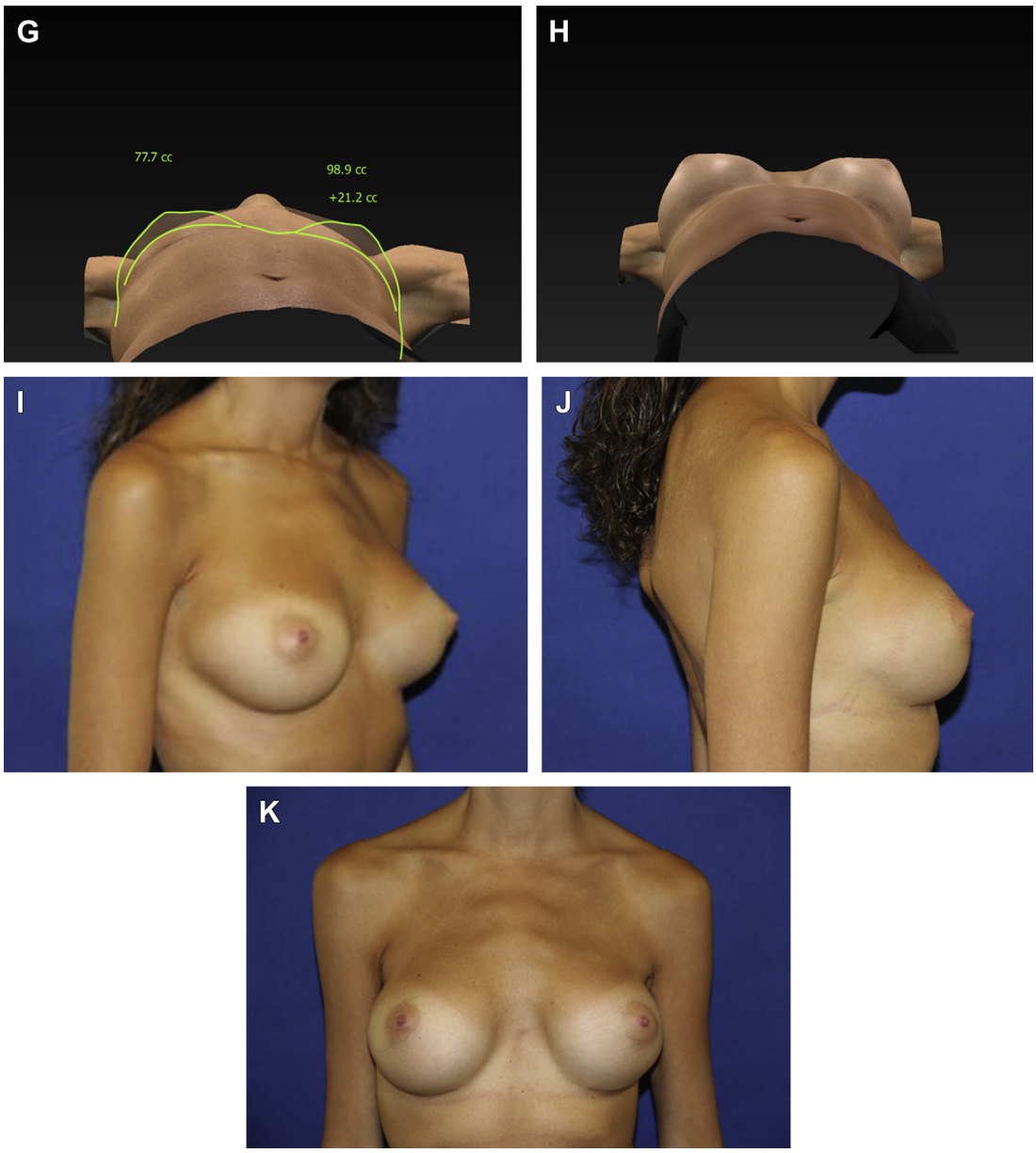

Fig. 4. (*continued*). (*G, H*) Preoperative and 1-year postoperative 3-dimensional simulation of the chest wall reveals improvement in projection of hypoplastic elements and symmetry. (*I–K*) Breast augmentation with style 410 FM270 right, FX315 left. Although there is not exact symmetry, the 3-year results remain stable.

breast augmentation cases; however, they may be useful in complex chest and breast asymmetries, especially in revision procedures. If used, care should be taken to limit the introduction of sizers to a bare minimum while using techniques to avoid contamination of the pocket. Finally, if the IMF has been adjusted, a sturdy suture repair that includes deep sutures from the chest wall to the fascia, followed by deep dermal sutures and skin, will help prevent inferior malposition and keep the incision well hidden in the new fold (**Fig. 8**).

ISOLATED BREAST ASYMMETRIES

By far, the most common deformities that a plastic surgeon will encounter are isolated breast asymmetries. These differences can be in volume alone, but more likely will also include

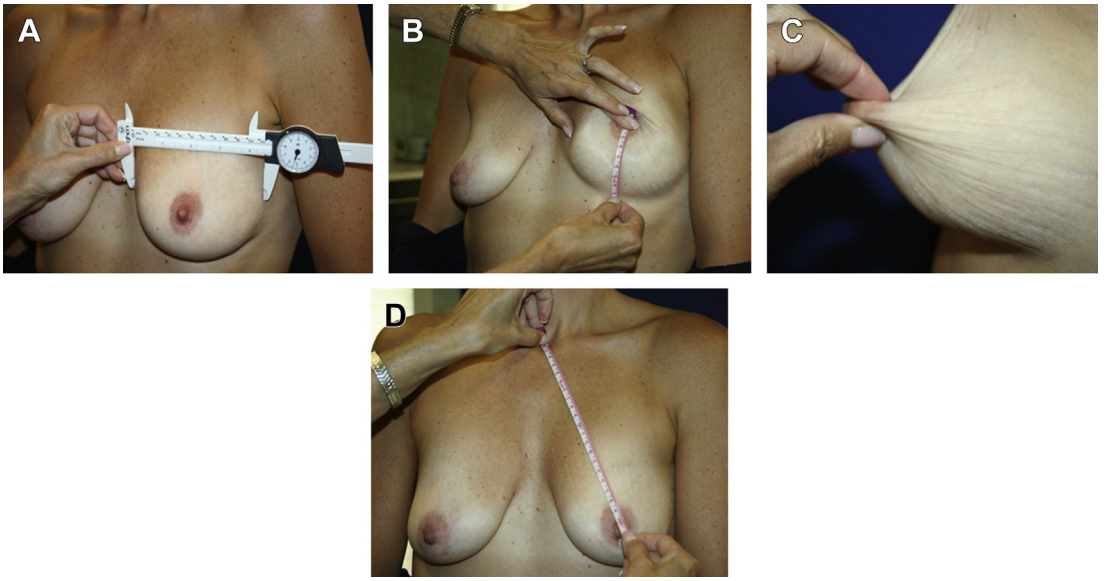

Fig. 5. (*A–D*) Tissue-based planning. (*A*) Base width—BW. (*B*) Nipple-to fold distance—N:IMF. (*C*) Breast type: skin stretch and elasticity. (*D*) Sternal notch-to-nipple distance-SN:N.

asymmetries in shape and parenchymal fill. The true beauty of the anatomic highly cohesive breast implant is its ability to produce shape while simultaneously adding volume, and the capacity to control the distribution of the gel.

During the initial consultation, the patient may initiate the discussion on breast asymmetry, but quite often it is only during the preoperative planning that the conversation about using 2 different implant styles or shapes begins. Some patients with breast asymmetries may not be aware of the extent of their asymmetry, while others are acutely aware of their dissimilar breasts. It is wise to document all objective measurements, 2-dimensional photographs, and computer scored measurements preoperatively and to thoroughly discuss these findings with the patient during the implant selection process. The availability of a full range of implant sizes and styles in the United States will finally allow surgeons the ability to fine-tune breast augmentation for women with asymmetries (**Figs. 9** and **10**).

CORRECTION OF BREAST AND CHEST WALL ASYMMETRY WITH IMPLANTS AND FAT

Fat transfer is becoming a more common procedure in the treatment of chest wall and breast deformities. When used in conjunction with shaped highly cohesive gel implants, autologous fat may be able to provide additional soft tissue coverage and contour improvements that implants alone may not be able

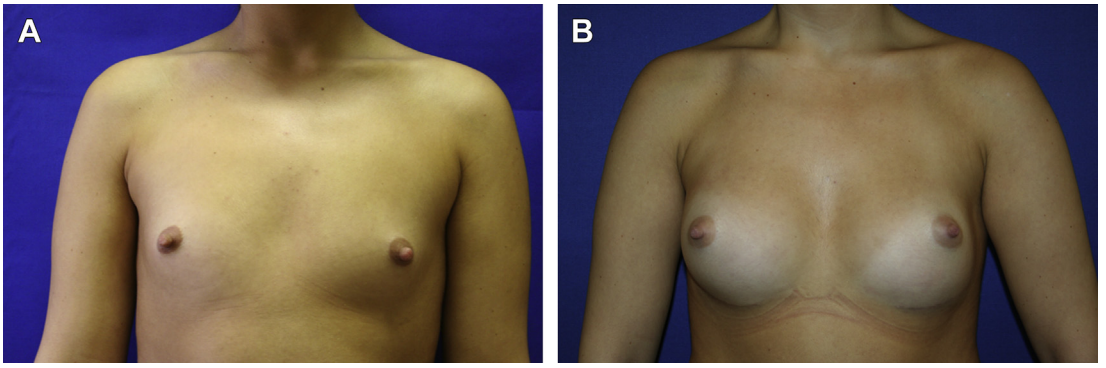

Fig. 6. (*A, B*) This patient underwent correction of her asymmetry with a style 410 MM320 on the left and an MF335 on the right. The nipple-to-fold distance was lowered on the right to match the lowered left. This resulted in both folds being placed too low and upward pointing nipples at 3 years.

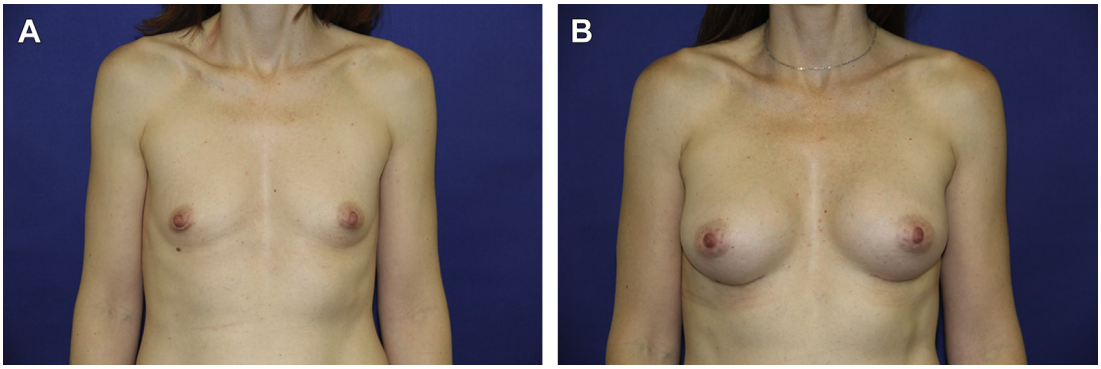

Fig. 7. (*A, B*) This patient underwent correction of her mild asymmetry with an MM280 on the left and an MF295 on the right. The nipple-to-fold distance was set at 7.8 cm on the left and 8.0 cm on the right. The location of the IMF may be different on each side, but the nipples will point forward not upward. 3-year result.

to achieve. Autologous fat transplantation to improve contour defects in breast reconstruction was described in 2005.[15] Chest wall deformities like pectus excavatum have been treated with lipomodeling as either an adjunct to minimally invasive procedures or alone in milder cases, with reported high satisfaction rates.[16] Composite breast augmentation can be defined as the simultaneous

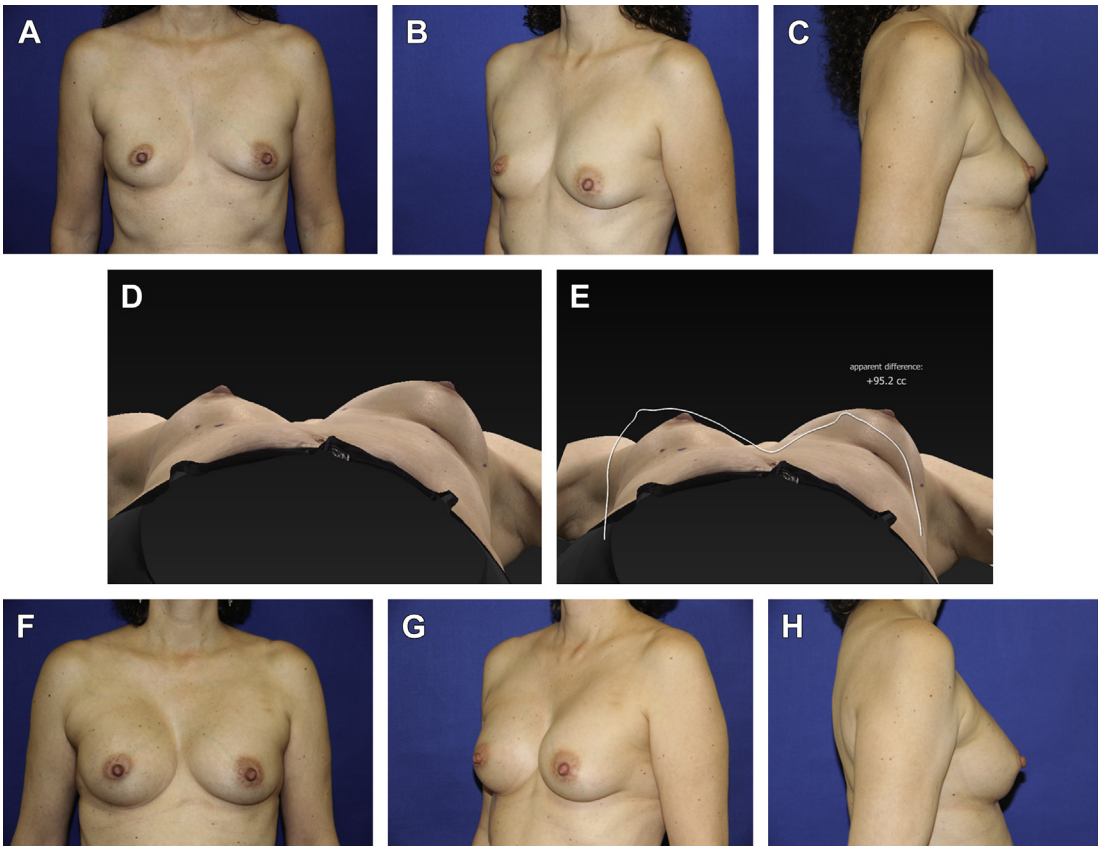

Fig. 8. (*A–E*) The preoperative photographs and 3-dimensional chest wall views, including a reflection view, can provide a better evaluation of the existing unilateral thoracic hypoplasia. (*F–H*) Style 410 FM270 right, ML125 left. Patient underwent a single lipofilling session at 2 years, with stable results at 3 years.

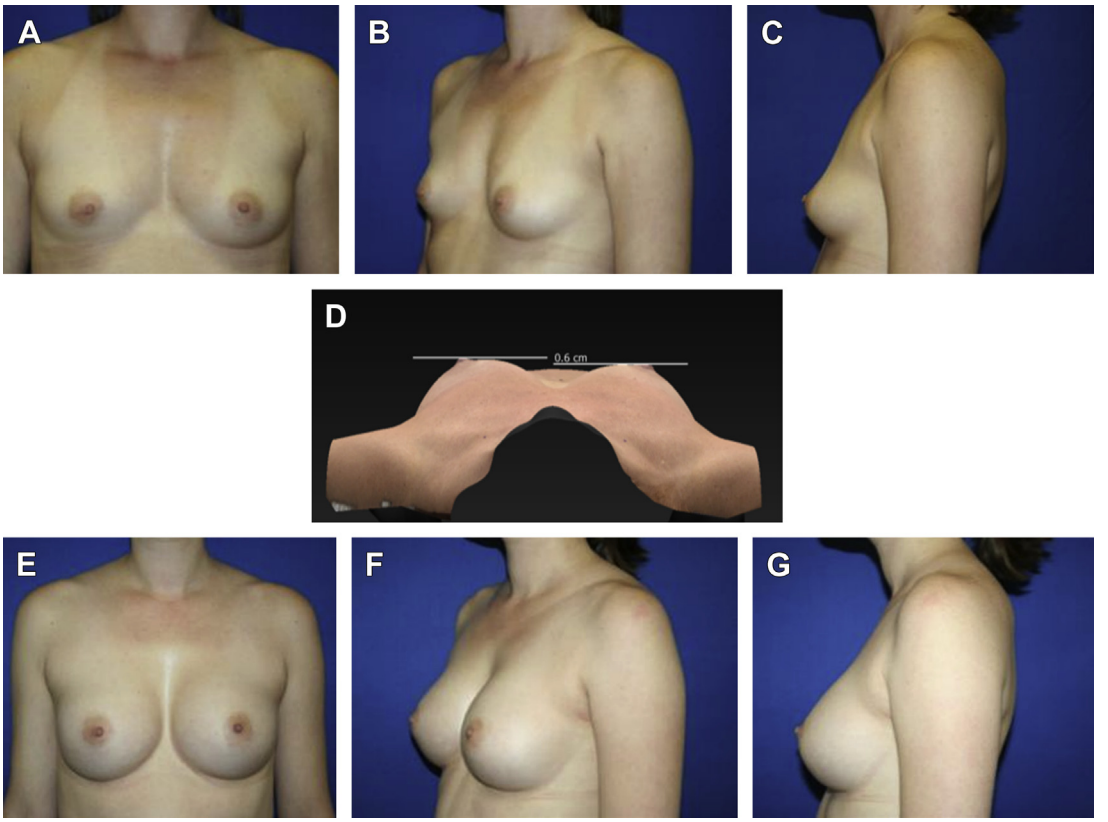

Fig. 9. (*A–D*) Preoperative 3-dimensional assessment reveals a .6 cm difference in projection between the left and right breasts. (*E–G*) Breast augmentation for asymmetry with style 410 MM280 left, MF295 right. Results at 3 years.

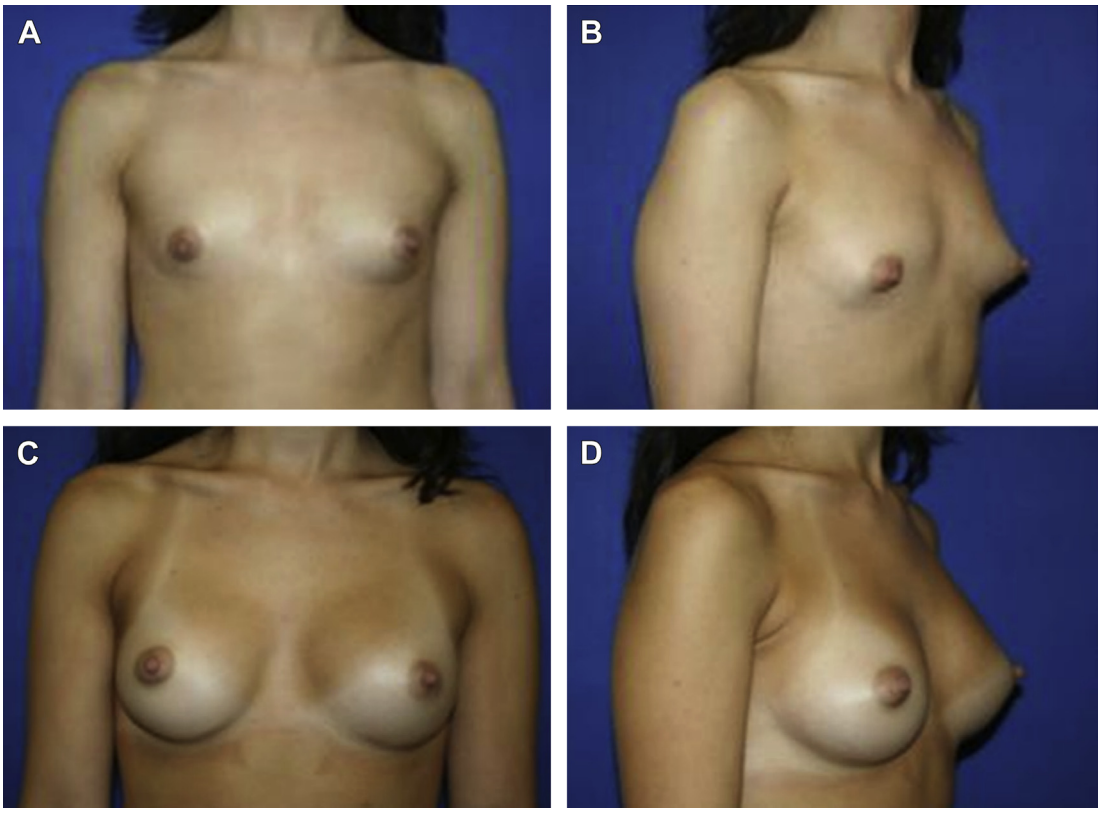

Fig. 10. (*A, B*) Preoperative views and (*C, D*) 5-year results in a patient with breast asymmetry and constricted base breast right. Right: 410 style MF255, left: 410 style MM245.

use of breast implants with autologous fat.[17] Some of the complications associated with large-volume transfer, such as calcifications and cysts, can be potentially be reduced when lower volumes of fat are required for fine-tuning the desired volume or shape. Fat transfer does not have to be performed at the time of augmentation and may be staged to further correct residual asymmetries or changes that occur with aging and time. With improvements and modifications in harvesting, processing, and injection techniques, there has been a documented increase in the survival rate of transferred fat. For younger patients with a very low body mass index (BMI), the benefits of harvesting fat must be weighed against the potential risks of additional donor site deformities and the possibility that harvesting sufficient fat may not be feasible. Fat grafting used in conjunction with shaped highly cohesive gel implants does offer further options for patients with moderate-to-severe chest wall deformities and breast asymmetry.

SUMMARY

Patients presenting for correction of breast and chest wall asymmetries may have undergone numerous thoracic procedures in early childhood, and some may have suffered profound psychosocial effects for years. Care must be taken to evaluate these patients using objective criteria and biodimentional principles. More complex congenital syndromes will require a more comprehensive preoperative work-up as well as a detailed history of any previous thoracic or breast procedures. Even the most mild of breast asymmetries needs to be carefully documented using measurements, photography, and 3-dimensional simulations when available. Patient education needs to be comprehensive, and patients need to understand that absolute correction of underlying chest wall and breast asymmetry may not be possible. Shaped highly cohesive breast implants offer plastic surgeons more possibilities and precision by fine-tuning the gel distribution and specific volume required to correct the hypoplastic elements. Preoperative planning and implant selection can be more interactive, with patient involvement in the decision-making process. Patients need to be willing to accept what can and cannot be corrected, and have realistic expectations. Long-lasting correction of asymmetry can be obtained when patients are not oversized, and care is taken to avoid visibility, palpability, and malposition problems. Finally, fat grafting for residual small defects is becoming a useful adjunct to the use of shaped implants alone.

Editorial Comments by Bradley P. Bengtson, MD

Some form of breast and chest wall asymmetry or deformity can be identified in essentially every breast augmentation patient. As one of my favorite mentors taught me: "Breasts are sisters not twins!". The preoperative assessment of the patient's chest wall and breasts are even more critical in these patients. 3-D imaging and simulation is extremely helpful in both planning and implant selection as well as setting patients expectations and establishing acceptable outcomes. In addition, shaped implants can provide a huge number of options with four different projection and three height options along with a large number of implant widths. In addition fat grafting or transfer is often important in achieving the best outcome in these patients thickening the soft tissues over thin asymmetric areas of the chest or over devices.

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