Three-dimensional surface imaging in pectus excavatum

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Impact paragraph

The aim of this chapter is to describe and elaborate on the scientific and societal impact achieved and anticipated by the current thesis.

Relevance for patients

The fundamental rationale for this thesis has been the routine exposure to potentially harmful ionizing radiation associated with current diagnostic procedures in the work-up of pectus excavatum. In the consecutive chapters, scientific basis was provided allowing the use of three-dimensional (3D) imaging as primary diagnostic modality in pectus excavatum with appropriate accuracy compared to current modalities.

Most patients seeking consultation for pectus excavatum concern those of pediatric age. Especially these patients are at risk to develop radiation associated pathologies due to their relatively long life-time risk, therefore pediatric patients are the ones who benefit most from the anticipated transition towards the use of 3D imaging as primary diagnostic modality in pectus excavatum. Yet, as radiation exposure is potentially hazardous for all age groups, adults benefit likewise.

Based on local preferences, pectus centers have up until now used either computed tomography (CT) or plain radiographs as primary screening modality. The global ratio is about 50:50. Considering this, it must be said that patients referred to a pectus center that already dispensed CT and employs plain radiographs instead still benefit, albeit to a lesser extent because the associated effective radiation dosage of plain radiography is lower than CT. Nevertheless, 3D imaging is strengthened by its potential use for follow-up, mitigating the cumulative radiation dose exposed to during the entire treatment course. On the other hand, a disadvantage of 3D imaging is its contraindication in patients with any form of light hypersensitivity.

As mentioned, about half of all pectus centers primarily employ plain chest radiographs during work-up. These centers and their patients benefit from the possibility to predict cardiac compression from 3D images which would otherwise require additional diagnostics. Yet, in the presence of a patient presenting with a story of impairing cardiac symptoms and a low model-predicted probability for compression, the patient may need further analysis.

Currently, 3D images are obtained by dedicated imaging systems for which a hospital visit is required. Although these investigations are often clustered to reduce the number of outpatient visits, it is anticipated that follow-up and even primary consultation including 3D imaging can be done completely through videoconferencing. Tablets and mobile phones already come with a light detection and ranging scanner allowing the acquisition of 3D images, with intuitive software and applications allowing easy utilization at home. This is specifically valuable given the relatively large adherence area of tertiary pectus referral centers. In addition, the possibility may be created for patients to send a 3D image of their chest to obtain a preliminary advice, aiming to overcome the general unawareness on pectus excavatum among first-line caregivers. Currently, patients are often referred to a pectus specialist center rather late, after conducting their own search through web-based sources.

Relevance for clinical practices

Adopting 3D imaging is, as with all technical novelties, forecasted to unfold rather slowly due to the necessary infrastructural changes, monetary investments, the general viscosity of changes in medicine, and the primary initiative which must often be taken by local pectus experts who recognize its potential. On the other hand, after renowned pectus centers worldwide begin using 3D imaging, a snowball effect may be expected. To advance this effect, the scientific evidence for 3D imaging should be expanded, to which this thesis contributes.

Three-dimensional imaging requires trained operators for acquisition and processing of the acquired raw data. The most logical step would be to educate medical photographers to do so (as done in our center) since they understand the basic principles of digital imaging and are housed in most centers. Moreover, 3D imaging is often regarded as a step-up from conventional two-dimensional photography. However, first the 3D imaging system of choice needs to be purchased, alongside the required information communication technology upgrades, including storage, software and so on. Potentially, this is a major barrier to medical centers since the cost-effectiveness compared to current diagnostic procedures remains unknown. One way to cut costs would be to centralize pectus care in tertiary referral centers, which has already naturally occurred in the Netherlands. In addition, 3D imaging can be employed in other fields than thoracic surgery, such as plastic surgery and oral and maxillofacial surgery where its medical use originated. Moroever, given its inexhaustible potential of applications in analysis, follow-up and surgical planning, the burden of investment may be diluted among various departments. Besides, 3D imaging systems are readily commercially available for less than $1000. In short, adopting 3D imaging requires careful weighing and subsequent planning with inclusion of all stakeholders. Three-dimensional imaging is not superior to current diagnostic procedures in terms of accuracy but primarily aims to shield patients from potentially harmful ionizing radiation. Although scientifically proven, significant unawareness on associated risks of radiation exposure remains globally, resulting in its inconsiderate use.

Relevance for pectus society

In the past decades, research on pectus excavatum exponentially grew. However, relatively little is still known about the deformity itself whereby visual examination and diagnosis remains rather subjective, henceforth urging the need for standardization. Here is a major role for 3D imaging as it allows objective quantification of pectus excavatum and its morphological features. Using such objective measures is anticipated to provide a common language among experts. However, interpretation of these numeric values could mutually be subject to observer differences since their severity is judged according to the expert's reference frame. This could be overcome by using a concept like growth curves where deviations from the mean are identified. For example, a severity several standard deviations below the mean, could be labeled as a non-severe pectus excavatum.

Another issue that may be overcome is the subjective recurrence of pectus excavatum reported by patients during follow-up after bar removal which is often not recognized or acknowledged by experts. In these cases, 3D imaging can provide objective measures.

In addition, part of cases who undergo repair of pectus excavatum are dissatisfied by the postoperative aesthetic result. Three-dimensional imaging could also be employed to provide a patient-specific prediction of the postoperative outcome, aligning expectations during preoperative consultation, and thereby reducing the likelihood for postoperative dissatisfaction about the aesthetic result.

In conclusion, although the use of three-dimensional imaging in pectus excavatum is still in its infancy, its usefulness is already apparent in daily practice by pioneering centers. The present thesis demonstrated the feasibility, validity and accuracy of three-dimensional imaging and evaluated several of its applications. We expect the share of three-dimensional imaging to only increase, especially in the objectification of pectus excavatum which remains a rather subjective diagnosis. Still, future studies should aim to address the limitations and future directions elaborated on, ensuring its solid scientific embedding.