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Computer-Assisted Quantitative Mitral Valve Surgery

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Mitral valve reconstruction is a wide-spread surgical method to repair incompetent mitral valves, which has shown to be beneficial in comparison to valve replacement. Surgical correction demands for capturing and interpretation of the valve's pathophysiology in order to choose for the appropriate repair strategy. Yet, common perioperative analysis of the mitral valve are merely based on operator-dependent assessment, which does not allow for a comprehensive objective assessment of its complex three-dimensional morphology. Moreover, surgical decisions are often made according to the surgeon’s subjective experience due to the lack of explicit scientific evidence.

Within the scope of this thesis, novel computer-based techniques were developed and evaluated for assisting mitral valve diagnosis and surgery on a quantitative basis. An automatic mitral valve leaflet segmentation approach is presented for clinical time-resolved transesophageal echocardiographic data. The proposed algorithm is able to segment all volumes from a given data set and is superior to existing state-of-the-art concepts in terms of accuracy and robustness. Dynamic geometric descriptions of the leaflets can be derived from the resulting mitral valve models, enabling clinicians to quantitatively specify different pathological variations.

To facilitate objective intraoperative measurements and decision support, an optical tracking-based assistance system is proposed for capturing the distorted mitral valve morphology. The results of a phantom study show that highly accurate and objective landmark measurements provide a comprehensive geometric description of the complex valve morphology. The novel geometric descriptions enable a reproducible prosthetic ring selection for mitral valve annuloplasty, potentially overcoming ambiguous traditional ring sizing procedures. Supplemental to this, an endoscopy based augmented reality visualisation method for ring selection is presented, which generates a virtual preview of the resulting orifice to be expected after ring implantation.

The intraoperative assistance system was applied in patients during nine mitral valve surgeries. The novel optical tracking measurement steps integrated well with the traditional workflow. Computer-based proposals for the size of an adequate ring prosthesis coincided with the surgical choice. The surgeon furthermore reported that his three-dimensional perception of the surgical target was substantially enhanced by the three-dimensional visualisation and the quantitative parameters. Yet, to show the efficacy of the system with regard to patient outcome was beyond the scope, but need certainly be done to facilitate a continuous integration into clinical routine.

In conclusion, the approaches solve major issues of current subjective analysis and demonstrate the potential to integrate quantitative description of the mitral valve in clinical routine, therefore making decision finding more objective, standardised and easier comprehensible for surgeons.