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Evaluating the Effect of Three-Dimensional Visualization on Force Application and Performance Time During Robotics-Assisted Mitral Valve Repair

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Objective: The purpose of this study was to determine the effect of three-dimensional (3D) binocular, stereoscopic, and two-dimensional (2D) monocular visualization on robotics-assisted mitral valve annuloplasty versus conventional techniques in an ex vivo animal model. In addition, we sought to determine whether these effects were consistent between novices and experts in robotics-assisted cardiac surgery.

Methods: A cardiac surgery test-bed was constructed to measure forces applied during mitral valve annuloplasty. Sutures were passed through the porcine mitral valve annulus by the participants with different levels of experience in robotics-assisted surgery and tied in place using both robotics-assisted and conventional surgery techniques.

Results: The mean time for both the experts and the novices using 3D visualization was significantly less than that required using 2D vision ($P < 0.001$). However, there was no significant difference in the maximum force applied by the novices to the mitral valve during suturing ($P = 0.7$) and suture tying ($P = 0.6$) using either 2D or 3D visualization. The mean time required and forces applied by both the experts and the novices were significantly less using the conventional surgical technique than when using the robotic system with either 2D or 3D vision ($P < 0.001$).

Conclusions: Despite high-quality binocular images, both the experts and the novices applied significantly more force to the cardiac tissue during 3D robotics-assisted mitral valve annuloplasty than during conventional open mitral valve annuloplasty. This finding suggests that 3D visualization does not fully compensate for the absence of haptic feedback in robotics-assisted cardiac surgery.

Key Words: Visualization, Haptics, Robotics-assisted cardiac surgery.

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Robotic surgical systems assist surgeons in performing minimally invasive procedures, through their provision of high-definition stereoscopic imaging and wristed suturing capability through smaller endoscopic ports. Because of these engineering advances, the surgical robot reduces tremor at the instrument and increases surgeons' dexterity.[1,2] However, robotic surgical systems present new and unique challenges resulting from the use of indirect visualization through an endoscope and remote manipulation of tissue through a master-slave configuration.[3] It is well established that in conventional or open surgery, sensory input is derived from both vision and haptic feedback.[4,5] Haptics is the combination of kinesthetic, tactile, and proprioceptive information. Kinesthetic feedback provides position, force, and movement information and can be measured using a force/torque sensor. Tactile feedback includes the sensation of vibration, shape, and texture. Proprioception provides the sense of position and movement of body segments.[2] For a complete depiction of haptic interactions between surgical instruments and tissue, kinesthetic, tactile, and proprioception feedback must be acquired.[2,6,7]

During robotics-assisted surgery, the indirect manipulation of tissue through the master-slave configuration of the robotic system prevents realistic interaction forces between the surgeon, the therapeutic instruments, and the tissue.[3] This may be particularly deleterious in dexterous fine movements such as intracorporeal suturing and knot tying, which require accurate

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control of applied forces and instrument positions.[2,8–10] Without haptic feedback, insufficient forces might be applied when grasping tissue or sutures, resulting in loose knots.[2,3] Conversely, excessive forces may be applied to tissue, leading to increased trauma and damage to tissue.[2,3] This is particularly important in robotics-assisted mitral valve repair, which requires fine motor skill to suture an annuloplasty band to the cardiac tissue surrounding the mitral valve annulus.

Without tactile and force information, surgeons must rely on visual cues to estimate the force being applied.[2,4,5,11] To accommodate this requirement, Intuitive Surgical Incorporated (Sunnyvale, CA USA) has developed the da Vinci surgical system with a very high quality three-dimensional (3D) stereoscopic visualization system to enhance the performance of robotics-assisted surgical procedures.[7,12,13] Throughout this article, we refer to the stereoscopic and monoscopic visualization modes as 3D and two-dimensional (2D), respectively. Although some have argued that the da Vinci's superior 3D visualization capabilities compensate for the lack of haptic feedback, others assert that visualization alone cannot replace the value of force feedback.

The objective of this study was to determine the effect of 3D visualization on the amount of force applied to mitral valve tissue and the time to perform ex vivo mitral valve annuloplasty using robotics-assisted and conventional techniques. In addition, our aim was to determine whether these effects are consistent between novices and experts in robotics-assisted cardiac surgery. Finally, to add further clinical relevance, we compare these results with those of conventional open mitral valve annuloplasty to examine differences in forces applied and times required to complete surgical tasks between robotics-assisted and conventional open surgery.

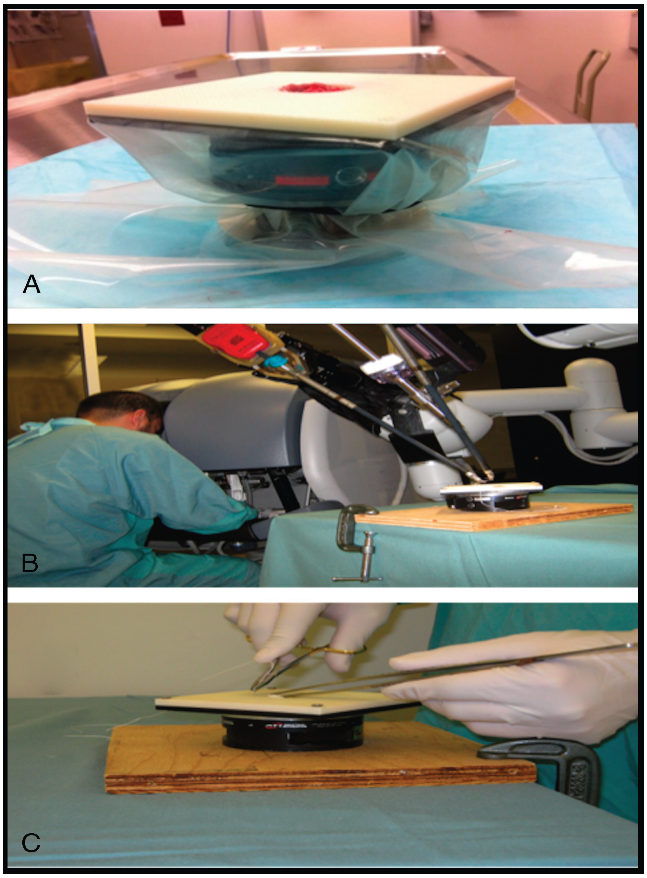

FIGURE 1. A, Mitral valve annuloplasty test-bed. The tissue test-bed consists of an excised porcine mitral valve mounted between two custom-designed plates that firmly clamp the cardiac tissue along the outer edge of the annulus. The plates and the valve are mounted on a six-axis force/torque sensor (ATI Industrial Automation, Apex, NC USA). B, Mitral valve annuloplasty test-bed within the operative field of the da Vinci robot. C, Mitral valve annuloplasty test-bed used for conventional valve repair.

METHODS

Mitral Valve Annuloplasty Test-Bed

A cardiac surgery test-bed was constructed to measure forces applied by the test subjects performing either conventional or robotics-assisted mitral valve annuloplasty. The tissue test-bed consisted of a porcine mitral valve mounted on a six-axis force/torque sensor (ATI Industrial Automation, Apex, NC USA) to measure applied forces in the x, y, and z directions (Fig. 1). The porcine mitral valve annulus and the attached leaflets were dissected from the porcine chordae tendinae attachments and the left ventricle. A disk to mount the mitral valve on the force/torque sensor and expose the valve annulus and the leaflets was designed and constructed using SolidWorks (Dassault Systèmes SolidWorks Corporation, Waltham, MA USA). The disk was printed from ABSplus production-grade thermoplastic (Dimension Incorporated, Eden Prairie, MN USA) using the Elite 3D printer (Dimension Incorporated, Eden Prairie, MN USA). The excised mitral valve was mounted between the two custom-designed plates that firmly clamp the cardiac tissue along the outer edge of the annulus (Fig. 1). Custom software was written in C++ to record forces applied to the porcine mitral valve and measured by the force/torque sensor every 1 millisecond. Multiple studies have used porcine mitral valves as a model of the human mitral valve for force modeling, pathology modeling, surgical techniques, surgical skills training, and surgical outcomes.[14–21] In fact, a recent study compared the biomechanical properties of the human mitral valve with the porcine mitral valve and found that the annular and the leaflet geometry of the porcine and human mitral valves are very close in dimensions; however, porcine mitral valves are more compliant than are human valves.[22]

Selection of Subjects

After approval from the Western University Ethics Review Board, cardiac surgeons with experience in both conventional and robotics-assisted cardiac surgery, along with medical trainees with no experience in robotics-assisted surgery, were contacted to participate in this study. Nine study participants completed both conventional and robotics-assisted mitral valve annuloplasty trials. Three participants were surgeons with training in both conventional and robotics-assisted cardiac surgery, whereas six were trainees with no experience in robotics-assisted procedures. The three expert participants had each completed more than 500 robotics-assisted cardiac operations as part of their specialized training and surgical practice before the study. One of the three experts was left handed. The novice group consisted of cardiac surgery residents from postgraduate year 1 to postgraduate year 6. None of the residents had completed a robotics-assisted cardiac surgery before the study. However, all residents had experience in conventional suturing and knot tying in cardiac surgery. One of the six trainees was left handed. All other participants were right handed.

Assessment of Forces and Time Required for Conventional Mitral Valve Annuloplasty Tasks

The study subjects completed conventional mitral valve annuloplasty within the mitral valve annuloplasty test-bed. Each subject passed sixteen 75-cm 2-0 (V-5) Ethibond sutures (Ethicon Inc, Somerville, NJ USA) through the porcine mitral valve annulus in a transverse mattress fashion at predetermined points using the same 6-in Crile-Wood needle driver and 8-inch DeBakey tissue forceps (Pilling, Canada Teleflex Medical, Markham, Ontario, Canada). The sutures were then passed through a Cosgrove-Edwards flexible annuloplasty band (Edwards Lifesciences Corp, Irvine, CA USA) and tied in place. The entire stitch length was not pulled through the annulus. Force and time were recorded: (*a*) from contact of the needle with the mitral valve annulus to complete withdrawal of the needle from the mitral valve annlulus, (*b*) from contact of the needle to the annuloplasty band to complete withdrawal of the needle from the annuloplasty band, and (*c*) from initiating the first loop for tying two forehand surgeon's knots and one backhand knot to tightening the last knot before the surgeons removed their instruments from the suture. There was no surgical assistant for any of the trials. All surgeons completed suture placement at standardized demarcated points along the posterior annulus of the mitral valve.

Assessment of Forces and Time Required for Robotics-Assisted Mitral Valve Annuloplasty With 2D and 3D Visualization

Mitral valve annuloplasty was completed by the study subjects as described above, using robotics-assisted techniques and the da Vinci Surgical System (Intuitive Surgical Inc, Sunnyvale, CA USA). The da Vinci was randomly switched between 2D and 3D visualization modes. Eight sutures and four ties were completed by the study subjects for both 2D and 3D visualization modes. The forces applied by the study subjects during three different force actions (inserting the needle into the mitral valve annulus, inserting the needle into the annuloplasty band, and suture tying) were measured by the force/torque sensor and recorded by the customized software. In addition, the time taken to execute three instrument ties was recorded. The maximum force measurement acquired by the force/torque sensor during each suturing or tying task was recorded for each surgeon. The mean of these maximum forces was calculated for the experts and the novices using 2D visualization, 3D visualization, or conventional techniques.

Statistical Analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (IBM, Corp, Armonk, NY USA). Univariate analysis of variance was used to compare force and time measurements completed by the subjects using conventional mitral valve annuloplasty and robotics-assisted mitral valve annuloplasty with either 2D or 3D visualization. Continuous variables are expressed as mean with SEM (SE). $P < 0.05$ was considered statistically significant.

RESULTS

Assessment of Time Required for Robotics-Assisted Mitral Valve Annuloplasty With 2D and 3D Visualization

The mean time required to suture the mitral valve annulus using 3D visualization was significantly less than that required to suture the mitral valve annulus using 2D vision ($P < 0.001$, Table 1). This finding was consistent between the experts and the novices ($P = 0.5$). In addition, there was no significant difference in suture times between the experts and the novices with either 2D or 3D visualization ($P = 0.8$). Similarly, the mean time required to tie a suture to the mitral valve annulus using 3D visualization was significantly less than the mean time required to tie using 2D vision ($P < 0.001$, Table 1). This finding was consistent between the experts and the novices ($P = 0.9$). However, the experts required significantly less time than the novices to tie sutures using either 2D or 3D visualization ($P = 0.03$).

TABLE 1. Comparison of the Time Required by the Experts and the Novices During Robotics-Assisted Ex Vivo Mitral Valve Annuloplasty With 2D and 3D Visualization and With Robotics-Assisted and Conventional Surgical Techniques

Measurement	2D	3D	*P*	Robotics-Assisted Surgery With 3D Visualization	Conventional Surgery	*P*
Mitral valve suture time, s						
Expert	49.4 ± 4.1	25 ± 3.2	<0.001	25 ± 3.2	12.4 ± 1.8	<0.001
Novice	45 ± 2	26.8 ± 1.9	<0.001	26.8 ± 1.9	19.4 ± 1.4	<0.001
Expert versus novice (*P* value)			0.8			0.004
Mitral valve tie time, s						
Expert	105 ± 15.2	63.5 ± 11.2	<0.001	63.5 ± 11.1	17.6 ± 8.2	<0.001
Novice	145.5 ± 9.5	97.7 ± 9.5	<0.001	97.7 ± 9.5	19.3 ± 6.4	<0.001
Expert versus novice (*P* value)			0.03			0.002

2D indicates two-dimensional; 3D, three-dimensional.

Assessment of Time Required for Mitral Valve Annuloplasty With Robotics-Assisted and Conventional Cardiac Surgery Techniques

The time required to complete suturing and tying tasks during ex vivo mitral valve annuloplasty using conventional techniques was compared with that required to complete these tasks using robotics-assisted techniques with 3D visualization. The mean time required to suture the mitral valve annulus using conventional surgical technique was significantly less than that needed to suture using robotics-assisted assistance and 3D vision ($P < 0.001$, Table 2). This finding was consistent between both experts and novices ($P = 0.1$). However, the experts required significantly less time than the novices to suture using either 3D visualization or conventional surgical technique ($P = 0.004$).

The mean time required to tie a suture to the mitral valve annulus using conventional surgical techniques was significantly less than that needed to perform the same task using robotics-assisted techniques with 3D vision ($P < 0.001$, Table 1). This finding was consistent between both experts and novices ($P = 0.1$). However, the experts required significantly less time than the novices to tie sutures using either robotics-assisted techniques with 3D vision or conventional surgical technique ($P = 0.002$).

Assessment of Forces Applied During Robotics-Assisted Mitral Valve Annuloplasty With 2D and 3D Visualization

The mean forces applied by the study subjects were measured and recorded during three different force actions: (*a*) inserting the needle into the mitral valve annulus, (*b*) inserting the needle into the annuloplasty band, and (*c*) suture tying. The mean maximum force applied during suturing of the mitral valve annulus using 3D visualization was significantly less than that applied to suture using 2D vision in the experts; however, there was no significant difference in the mean maximum force applied by the novices using either 3D or 2D visualization (Table 2). This finding was consistent between both experts and novices ($P = 0.3$). In addition, there was no significant difference in the force applied by the experts or the novices using 2D or 3D visualization ($P = 0.5$).

There was no significant difference in the mean maximum force applied to mitral valve tissue during suturing of the mitral valve annuloplasty band with either 3D visualization or 2D visualization (Table 2). This finding was consistent between both experts and novices ($P = 0.8$). In addition, there was no significant difference in the force applied by the experts or the novices using 2D or 3D visualization ($P = 0.8$).

Finally, the mean maximum force applied during suture tying using 3D visualization was significantly less than the mean maximum force applied using 2D vision in the experts ($P = 0.006$). However, there was no significant difference in the mean maximum force applied by the novices using either 3D or 2D visualization (Table 2). In addition, the experts applied significantly less force than the novices during suture tying using either 2D or 3D visualization ($P = 0.001$).

Assessment of Forces Applied During Mitral Valve Annuloplasty With Robotics-Assisted and Conventional Cardiac Surgery Techniques

The mean maximum force applied when suturing the mitral valve annulus using the conventional surgical technique was significantly less than the mean force applied to the suture using robotics-assisted techniques with 3D vision (Table 2). This finding was consistent between both experts and novices ($P = 0.5$). In addition, there was no significant difference in the force applied by the experts or the novices using robotics-assisted techniques with 3D vision or conventional techniques ($P = 0.9$).

The mean maximum force applied when suturing the mitral valve annuloplasty band during conventional surgery was significantly less than the mean suturing force applied during robotics-assisted techniques with 3D vision (Table 2). This finding was consistent between both experts and novices ($P = 0.6$). In addition, there was no significant difference in the force applied by the experts or the novices using robotics-assisted techniques with 3D vision or conventional techniques ($P = 0.6$).

TABLE 2. Comparison of the Force Applied by the Experts and the Novices During Robotics-Assisted Ex Vivo Mitral Valve Annuloplasty With 2D and 3D Visualization and With Robotics-Assisted and Conventional Surgical Techniques

Measurement	2D	3D	*P*	Robotics-Assisted Surgery With 3D Visualization	Conventional Surgery	*P*
Mitral valve annulus force, N						
Expert	4.6 ± 1.2	5.1 ± 0.9	0.7	5.1 ± 0.8	2.6 ± 0.5	<0.001
Novice	6.8 ± 0.6	4.8 ± 0.6	0.1	4.8 ± 0.6	2.8 ± 0.4	0.06
Expert versus novice (*P* value)			0.5			0.9
Annulopasty band force, N						
Expert	4.5 ± 0.5	4.2 ± 0.4	0.7	4.2 ± 0.4	1.6 ± 0.3	<0.001
Novice	4.8 ± 0.4	4.3 ± 0.4	0.7	4.3 ± 0.4	1.9 ± 0.3	<0.001
Expert versus novice (*P* value)			0.8			0.6
Suture tie force, N						
Expert	5.8 ± 1.9	4.1 ± 1.5	0.006	4.1 ± 1.5	2.9 ± 1.2	0.02
Novice	13.9 ± 1.3	11.5 ± 1.3	0.6	11.5 ± 1.3	3.6 ± 0.9	<0.001
Expert versus novice (*P* value)			0.001			<0.001

2D indicates two-dimensional; 3D, three-dimensional.

The mean maximum force applied when tying the suture to the mitral valve annulus using the conventional surgical approach was significantly less than that applied to the suture using robotics-assisted techniques with 3D vision (Table 2). The experts applied significantly less force than the novices using either robotics-assisted techniques with 3D vision or conventional techniques ($P < 0.001$). However, the decrease in force applied to the cardiac tissue was significantly greater in the novices compared with the experts ($P = 0.001$).

DISCUSSION

Our results suggest that, when comparing 2D and 3D visualization when performing, the use of the latter mode results in significantly shorter robotics-assisted suturing and tying times. In addition, both the experts and the novices had significantly shorter suturing and suture tying times with 3D compared with 2D visualization. This is consistent with previous studies that demonstrate that 3D visualization is associated with shorter movement times and higher movement velocities than is 2D visualization.[23–26] In addition, binocular 3D visualization provides more depth cues than does monocular 2D visualization.[23,27] As a result, performance of surgical tasks with 2D vision requires the use of indirect monocular cues to compensate for the lack of depth perception.[23] These cues include the relative position of instruments, anatomic structure size, shading of light and dark, and texture grading.[28] There is no significant difference in the amount of time required by the novices or the experts to suture using robotics-assisted techniques on the da Vinci surgical system. This point illustrates how intuitive the da Vinci system is for novice surgeons to conduct suturing. However, robotics-assisted suture tying is a more complex task, and the novices required significantly more time than the experts to complete this task. Therefore, performance of detailed skills such as intracorporeal suturing, tying, and fine dissection with 2D visualization requires practice and experience.

Previous studies have illustrated the improvement in operative performance times by surgeons with increased experience.[29,30] One center reported a 95% decrease in operative times each time the case number for a surgeon doubled.[31] Although learning curves differ between centers, this is reflected in the faster tying times for the experts, who have completed more than 500 robotics-assisted procedures, versus the novices. As our results show, on average, the experts sutured each stitch 12.6 seconds faster and tied each knot 45.9 seconds faster with conventional techniques versus robotics-assisted techniques with 3D vision. Moreover, on average, the novices sutured each stitch 4.4 seconds faster and tied each knot 78.4 seconds faster with conventional techniques versus robotics-assisted techniques with 3D vision.

On an annuloplasty band with 10 double-armed stitches, the abovementioned results translate to a mean difference between conventional and robotics-assisted techniques with 3D vision for suturing and tying of 11.9 minutes in the experts and 14.5 minutes in the novices.

Our data also show that suture time with conventional open surgery required significantly less time than that required when using a robotics-assisted procedure, with either 2D or 3D visualization. Therefore, although the da Vinci surgical system provides true stereoscopic vision, there are other effects associated with the robotics-assisted approach that still create an increase in the task completion time. This conclusion is consistent with previous clinical studies that have reported longer operative times in robotics-assisted surgeries compared with conventional or open surgeries.[32–34]

Although previous studies have demonstrated superior performance curves and operative efficiency with 3D visualization, no previous studies have examined the effect of 3D visualization on force application on surgical tissue. These data suggest that there is no significant difference in the maximum force applied by the novices to the mitral valve during insertion of needle in the annulus, insertion of needle in the annuloplasty band, or during suture tying using either 2D or 3D visualization. However, there is a significant decrease in the force applied by the experts to the mitral valve tissue during suture tying with 3D visualization versus the corresponding forces with 2D visualization. The experts' mean maximum forces were also more consistent with 3D visualization, reflected as a smaller SE. In addition, the novices consistently applied significantly more force to the mitral valve tissue than did the experts using 2D or 3D visualization. One possible explanation for this is that the novices are less perceptive of visual cues to indicate the force applied to tissue. They may not have adapted to the lack of tactile or haptic feedback, whereas the experts have more experience using visual cues to guide the force applied to tissue.

The force applied to the cardiac tissue by the novices was consistently greater than that applied by the experts, particularly during suture tying. Previous studies[35] using porcine tissue have reported visible tissue damage with the application of an 11-N force over an area of 2.4 cm^2. In this study, the novices applied potentially damaging forces to the cardiac tissue using robotics-assisted techniques without haptic feedback. This suggests that haptic feedback may be particularly useful to novices using robotics-assisted techniques. Moreover, force application could potentially be used as a measure of surgical performance or expertise in evaluating trainees on robotics-assisted procedures; however, further validity testing is required to support such a hypothesis.

This study and others have demonstrated shorter operative times with 3D visualization; however, despite high-quality binocular images, both the experts and the novices applied significantly more force to the cardiac tissue during 3D robotics-assisted mitral valve annuloplasty than during conventional open mitral valve annuloplasty. The highest forces applied by the experts were still less than the force required to inflict any damage on the cardiac tissue; however, the novices applied potentially damaging force to the cardiac tissue using robotics-assisted techniques without haptic feedback. This finding suggests that 3D visualization does not fully compensate for the absence of haptic feedback in robotics-assisted cardiac surgery, particularly in novices. Therefore, although 3D visualization may provide more information regarding object depth to facilitate complex tissue grasping, 3D visualization may not provide adequate visual cues to reflect the force applied to the cardiac tissue. We have demonstrated that although robotics-assisted mitral valve repair provides many benefits to the patient, this technique poses further challenges to the surgeon and the surgical trainee. Robotics-assisted surgical tasks require additional time and may apply potentially damaging forces to the cardiac tissue, a factor that is more prominent in novice surgeons. A simulation system providing force feedback may improve both expert and trainee performance using robotics-assisted techniques. We plan to test this hypothesis in future studies. Our results demonstrate that robotics-assisted mitral valve repair requires more time, and surgeons apply more force to the cardiac tissue using robotics-assisted techniques compared with conventional mitral valve repair. Conventional or open mitral valve repair is technically challenging, and investigators have reported the improvement in trainee performance after simulation training for open or conventional mitral valve surgery.[17]

Because of this repeated-measures study design, the results may have been limited by subject fatigue after several trials, carry-over effects from one technique to the next, and the order of technique presentation. To minimize these effects, the order of trials with 2D and 3D visualization was randomized for each subject. In addition, the accuracy of suturing and the quality of suture tying by the novice study subjects were not assessed in this trial. Furthermore, our sample size was limited by the number of experts in robotics-assisted cardiac surgery. If we had included more participants to increase the power of the study, we may have been able to detect a significant decrease in the amount of force applied to the cardiac tissue with 3D visualization. We plan to address this limitation in future work.

In conclusion, although 3D visualization increases the control and the consistency of the interaction forces on the cardiac tissue, it does not prevent the application of damaging forces. The implication of these findings is that to achieve better control of the interaction forces on the cardiac tissue, haptic feedback may be required.

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CLINICAL PERSPECTIVE

This is another in a series of important articles by the group from Western University in London, Ontario, Canada, objectively examining the technology used in robotics-assisted cardiac surgery. In this study, the authors investigated the effect of three-dimensional (3D) versus two-dimensional (2D) monocular visualization on robotics-assisted mitral valve annuloplasty versus conventional techniques in an ex vivo model. This question was examined both in novices and experts in robotics-assisted cardiac surgery. Their findings were that 3D visualization significantly decreased the time required to perform the annuloplasty task when compared with 2D vision. However, there was no significant difference in the maximum force applied by the novices during either suturing or suture tying when comparing 2D and 3D visualization. The mean time required and the forces applied by both the experts and the novices were significantly less using the conventional surgical technique than when using the robotic system with either 2D or 3D vision. Their conclusion was that despite the high-quality 3D images, both the experts and the novices applied significantly more force to the cardiac tissue during robotics-assisted mitral valve annuloplasty than during conventional open mitral valve annuloplasty. Their findings suggest that 3D visualization does not fully compensate for the absence of haptic feedback and the other shortcomings of robotics-assisted surgery.

This is a provocative and well-performed study. Their data are important and consistent with previous work. Previous studies have demonstrated that 3D visualization is associated with shorter movement times and higher movement velocities when compared with 2D visualization (Falk V, Mintz D, Grunenfelder J, Fann JI, Burdon TA. Influence of three-dimensional vision on surgical telemanipulator performance. *Surg Endosc.* 2001;15:1282–1288; Servos P. Distance estimation in the visual and visuomotor systems. *Exp Brain Res.* 2000;130:35–47; Servos P, Goodale MA. Binocular vision and the online control of human prehension. *Exp Brain Res.* 1994;98:119–127). This study is also in agreement with previous studies that have shown longer operative times in robotically assisted surgery compared with conventional or open surgery both clinically and in experimental models (Folliguet T, Vanhuyse F, Constantino X, Realli M, Laborde F. Mitral valve repair versus sternotomy. *Eur J Cardiothorac Surg.* 2006; 29:362–366; Kam JK, Cooray SD, Kam JK, Smith JA, Almeida AA. A cost-analysis study of robotic versus conventional mitral valve repair. *Heart Lung Circ*. 2010;19:413–418; Mihaljevic T, Jarrett CM, Gillinov AM, et al. Robotic repair of posterior mitral valve prolapsed versus conventional approaches: Potential realized. *J Thorac Cardiovasc Surg*. 2011;141:72–80; Prasad SM, Prasad SM, Maniar HS, Chu C, Schuessler RB, Damiano RJ Jr. Surgical robotics: impact of motion scaling on task performance. *J Am Coll Surg.* 2004;199:863–868). Three-dimensional visualization did not overcome this shortcoming. This is likely due to a number of reasons, including the lack of haptic feedback and the suboptimal motion scaling that is characteristic of the only robotic system on the market. The greater force applied with robotic systems when compared with conventional surgery testifies to the fact that even with sophisticated 3D visualization, these systems would benefit from the addition of haptic feedback.