Describe an innovation/research area in interventional radiology and discuss its impact on current/future IR practices.

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This essay explores the applications of Virtual Reality (VR) and Augmented Reality (AR) in Interventional Radiology. VR refers to complete immersion and interaction with a 3D computer generated, viewer centred environment(1). Contrastingly, AR refers to co-registration of computer generated 3D images with real life objects(2). In 2018, the global AR/VR healthcare industry was worth $641 million and according to a recent report the industry is forecast to be worth $3.8 billion by 2020(3).

The progression of a trainee observing a complex procedure to performing it for the first time is a steep learning curve. Using VR, patients' anatomical data is extracted from previous cross-sectional imaging and rendered into 3D virtual computer-generated graphics which a trainee can use for training and simulation. Two meta-analyses carried out by Alaker et al and Nagendran et al, respectively, included randomized control trials (RCTs) comparing the performance of trainees using VR with trainees using traditional methods for surgical training(4,5). Both found that performance of trainees using VR was associated with reduced operative times, reduced error rates and increased accuracy.

VR can be utilised in procedural planning. In 2017, United States (US) based technology firm Echopixel gained US Foods and Drugs Administration (FDA) approval for 'True3DViewer'. This was the first licenced 3D VR platform for surgical planning. This kit has been used by interventionalists to plan trans-hepatic portosystemic shunts insertion specific to patient anatomy(6). This personalized approach promises higher probability of desired outcomes post-procedure.

At pre-operative consultations, VR can be utilised to better explain the procedure to patients thus increasing engagement. A RCT measuring pre-operative stress for patients undergoing neurosurgical procedures found an association between a VR pre-operative experience and lower levels of pre-operative stress compared to those patients undergoing a conventional pre-op(7). Additionally, VR can be utilised post-operatively to demonstrate the effect of an intervention and hence improve overall patient satisfaction.

The promise shown by AR/VR has limitations. The hefty size of the currently available head-mounted displays reportedly lead to fatigue with prolonged use and their narrow field-of-view limit usability(8). Software limitations of AR include mis-registration of computer-generated images with the real world due to system latency leading to a lag between the two. A lag of 1 millisecond translates to 1 millimetre of mis-alignment between the co-registered image and actual anatomy(9). This is significant for a system which aims to assist in precise anatomical navigation. Systems aiming for low latency are currently in development(9). Accompanied with development of faster operating systems and quicker internet speeds, these limitations may soon be overcome. Finally, further research is needed to compare AR/VR with existing methodologies using clinical, financial and safety metrics to clearly define their role in patient care.

Uniquely, Interventionalists are known as the 'disruptors' who have always challenged convention to came up with innovative devices and techniques delivering minimally invasive, effective care to patients. AR/VR, despite its limitations, shows revolutionary promise which must be explored further. For true

adoption to occur, Interventionalists must guide future development of these technologies by working closely with industry.

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