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Original Research

360° virtual reality video for the acquisition of knot tying skills: A randomised controlled trial

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ABSTRACT

Background: 360° virtual reality (VR) video is an exciting and evolving field. Current technology promotes a totally immersive, 3-dimensional (3D), 360° experience anywhere in the world using simply a smart phone and virtual reality headset. The potential for its application in the field of surgical education is enormous. The aim of this study was to determine knot tying skills taught with a 360-degree VR video compared to conventional 2D video teaching.

Material and methods: This trial was a prospective, randomised controlled study. 40 foundation year doctors (first year postgraduate) were randomised to either the 360-degree VR video (n = 20) or 2D video teaching (n = 20). Participants were given 15 min to watch their allocated video. Ability to tie a single handed reef knot was then assessed against a marking criteria developed for the Royal College of Surgeons, England, (RCSeng) Basic Surgical Skills (BSS) course, by a blinded assessor competent in knot tying. Each candidate then underwent further teaching using Peyton's four step model. Knot tying technique was then re-assessed.

Results: Knot tying scores were significantly better in the VR video teaching arm when compared with conventional (median knot score 5.0 vs 4.0 p = 0.04). When used in combination with face to face skills teaching this difference persisted (median knot score 9.5 vs 9.0 p = 0.01). More people in the VR arm constructed a complete reef knot than in the 2D arm following face to face teaching (17/20 vs 12/20). No difference between the groups existed in the time taken to construct a reef knot following video and teaching (median time 31.0s vs 30.5s p = 0.89).

Conclusion: This study shows there is significant merit in the application of 360-degree VR video technology in surgical training, both as an independent teaching aid and when used as an adjunct to traditional face to face teaching.

1. Introduction

360° virtual reality (VR) video is an exciting and evolving field. It allows the user to enter a totally immersive, 3-dimensional (3D) experience anywhere in the world using simply a smart phone and virtual reality headset. In April 2016, the world's first 360° VR surgery was streamed live [1]. The viewer was able to watch an operation from a 360° camera directly above the patient and immerse themselves in the workings of the operating theatre, viewing different angles of the operative field as if they were in the theatre moving around the operating table. The close-to-real-life perspective this new technology brings could potentially revolutionise surgical training.

In modern day surgical training, reduced working hours, rota pressures and the increasing use of alternative treatment modalities such as interventional radiology are changing a trainees exposure to certain procedures [2,3].Surgical trainees encounter numerous obstacles to time spent in the operating theatre enhancing their surgical skills. Virtual reality technology has the potential to bridge those obstacles, bring close to real life experiences, and accelerate learning curves. It is by evaluating the use of VR technology in this study that we can appreciate the potential benefits that can be gained from surgical trainees.

A fundamental skill that a surgical trainee is expected to learn and perfect during the early stages of their career is the ability to tie a reef knot. It is a skill that is traditionally taught in basic surgical skills courses worldwide. Videos are often used as an adjunct to aid

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Marking criteria	Marks Possible
1. Grasps thread	
Correctly	2
Needs correction	1
1. The first hitch	
Perfectly and beds knot with forefinger	4
Does not bed knot	3
With fumbling	2
Crossed/ capsized	1
Cannot complete	0
1. The second hitch	
Perfectly and beds knot with forefinger	4
Does not bed knot	3
With fumbling	2
Crossed/ capsized	1
Cannot complete	0
1. Finished knot	
Perfect (reef, tight)	3
Loose	2
Not a reef	1
Total (maximum=13)	

Fig. 1. Marking criteria used to assess knot tying ability.

development of this skill, typically in a two-dimensional (2D) format played on a standard high definition monitor. This study aimed to determine whether a 360° VR video improved knot tying skills when compared with conventional 2-dimensional (2D) video teaching. No previous study has evaluated the use of VR video in basic surgical training.

2. Methods

2.1. Trial design and randomisation

This trial was a prospective, randomised controlled study and is reported in line with the CONSORT criteria [4]. Two identical videos demonstrating a single handed surgical reef knot were produced using the Royal College of Surgeons, Basic Surgical Skills video as the basis for its content. The first video was recorded using an Iphone 7 (Apple) with the purpose of playing in high definition 2D format on a laptop screen. The second video was recorded using a 360-degree camera, Insta360™ Nano (Insta360™), with the purpose of being played through a virtual reality headset. Over a two-month period (July and August 2017), we ran four sessions at two hospitals. Forty foundation year doctors were randomised using a computerised random number generator, to either the 360-degree VR video (n = 20) or the 2D video (n = 20) arm (see CONSORT diagram, supplementary material). This was a fixed, simple randomisation process performed by an independent allocator not involved in the assessment of participants. The assessor was blinded to the allocated intervention. Participants were given 15 min to watch their allocated video followed by 5 min of independent practice. Junior doctors that were not of foundation level of training and non-training doctors were excluded from the study.

2.2. Outcomes

Ability to tie a single handed reef knot on a knot-tying jig (Ethicon, UK) using a 4 mm diameter, 45 cm length of cord was then assessed against a marking criteria (Fig. 1) developed for the Royal College of Surgeons, England, (RCSEng) Basic Surgical Skills (BSS) course [5]. Assessment was by a blinded assessor competent in knot tying. Each participant then underwent further face to face teaching using Peyton's four step approach [6]. Knot tying technique was then re-assessed after a further 5 min period of independent practice. There was no time limit allocated to the assessment of each participant. The assessment of the participant ended once either a reef knot had been performed or the participant declared that they were unable to progress further with the completion of the knot.

Table 1
Baseline characteristics of study participants for standard and virtual reality training.

		Standard (n = 20)	Virtual reality (n = 20)
Sex	Male	14	12
	Female	6	8
Dominant Hand	Right	17	18
	Left	3	2
Career level	Foundation Year 1	14	15
	Foundation Year 2	6	5
Previous attendance on surgical skills course	No	17	18
	Yes	3	2
Previous knot tying exposure	No prior	7	8
	Observed	7	7
	Performed in simulated setting	3	2
	Performed in clinical setting under supervision	3	3
	Performed in clinical setting independently	0	0
Surgical career aspiration	No	6	6
	Yes	8	9
	Undecided	6	5

Table 2
Knot tying scores and time taken to construct a knot for standard and virtual reality training.

Median knot tying score (range) maximum = 13			
	Standard video n = 20	Virtual reality video n = 20	p-value
Post video alone	4 (2–9)	5 (2–9)	0.0396
Post video + face to face teaching	9 (2–13)	9.5 (6–13)	0.0141
Median time taken to construct a complete single handed reef knot in seconds (range)			
	Standard video n = 12	Virtual reality video n = 17	p-value
Post video + face to face teaching	30.50 (22–41)	31.00 (19–44)	0.8942

2.3. Statistics

Continuous variables are presented as median and range. Differences between the two groups in median knot scores and total time taken to complete a knot were analysed using the Mann-Whitney *U* test. We defined a significant result as a difference in knot tying skills between two standard cohorts on a BSS course. The RCSEng have a maximum number of 20 participants per course, thus we included 20 trainees in each group. A p-value of < 0.05 was considered statistically significant. All analyses were performed using Stata version 13.1.

3. Results

The results from all 40 trainees were included in the analysis. There were no losses after randomisation or due to exclusion. Baseline characteristics between the two groups were broadly similar (Table 1). Using video teaching alone, knot tying scores were significantly better in the 360-degree VR video arm (median knot score 5.0 vs 4.0 p = 0.04) (Table 2). When video teaching was used in combination with face to face teaching, this difference persisted (median knot score 9.5 vs 9.0 p = 0.01) (Table 2). More people in the 360-degree VR video arm constructed a complete reef knot than in the 2D arm (17/20 vs 12/20). No difference between the groups existed in the time taken to construct a reef knot (median time 31.0s vs 30.5s p = 0.89) (Table 2).

4. Discussion

4.1. Key findings

This single blinded RCT shows 360-degree VR video to be superior to conventional 2D video in the acquisition of knot tying skills. This is the case for video teaching alone, and when combined with traditional face to face skills teaching. To our knowledge this is the first study to investigate the potential educational benefits of 360-degree VR video in surgery.

4.2. Comparison with published literature

Technologies permitting different viewing angles have been shown to be of benefit in medical education and surgical training. These include the use of 3D computer graphics to supplement the teaching of anatomy. In a randomised controlled trial, students scored better on a multiple choice exam when they received a 3D lecture compared to a 2D power point presentation [7]. In a further study, participants performing basic laparoscopic tasks did so significantly better with the aid of 3D visualisation compared with 2D [8]. Much of the work published describing the use of VR technology in surgery comes from the use of computer generated simulated models viewed in 2D or 3D format allowing the user to simulate surgical procedures. Although not directly related to the technology used in this study, the majority of randomised controlled trials demonstrate a beneficial impact [9], with transfer of skills to the operative setting [10,11]. The drawbacks of these technologies is that they are often expensive, require complex computer programming to generate, are fixed in their location of use and ultimately the experience generated is artificial. In comparison, VR 360-degree videos differ from VR simulation, as the videos provide a close-to real life perspective. These videos do not use graphics or simulations to create an artificial environment, but instead are recordings of the real world, viewed using a headset. These videos overcome the drawbacks associated with VR simulations with regards to cost, ease of use and the artificial experience created.

4.3. Strengths and weaknesses

This study showed 360 VR to be a superior teaching aid in a typical group of junior doctors who were learning to tie knots. The findings are generalizable because the participant characteristics and teaching methods used here are similar to those seen on BSS courses throughout the world. The technology itself is a real life video recording where a view in every direction is recorded at the same time, typically shot using an omnidirectional camera. During playback the viewer has control of the viewing direction like a panorama which has the key advantage of providing additional viewing angles not seen with conventional 2D video. It is important to stress that during this study, the quality of both the VR 360-degree video and the conventional 2D video were recorded and viewed in high definition format. The standard video was recorded using an Iphone capable of high definition playback, however a quality control of both videos was not performed to ensure both videos were of the same quality prior to their use in the study.

This technology is becoming increasingly affordable, is easily accessible, portable and user friendly. The cost of a headset is highly variable, however it can cost as little as £1.50 for the most basic product. All smartphones are capable of playing VR formatted videos and therefore those trainees in possession of a smartphone will only need to purchase a headset.

Surgery is a craft specialty and not everybody possess the dexterity and coordination required to, for example, tie a one-handed reef knot. A

potential criticism of this study is that because more participants were able to tie a knot using 360 VR, we may have lowered the bar and encouraged less dextrous individuals to pursue a surgical career. However, we feel that any adjunct to learning is likely to have a positive effect upon a trainee's performance. A limitation of the technology is that although widely regarded as a virtual reality, it should be noted that with 360-degree VR video the locations of viewers are fixed, viewers are limited to the angles captured by the cameras, and they cannot interact with the environment.

A further limitation of this study is that the participants were not reassessed a few weeks later to see if there was a difference in skill retention between the two arms. It is possible that any improvement seen may not be retained unless the trainee continues to perform this skill regularly, which is true for all newly developed skills and techniques.

4.4. Areas for future research

The potential for application of 360-degree VR video in the field of surgical training is enormous. In this study, the ability to perform a single handed reef knot was assessed, however future studies could assess the benefit of VR technology in the acquisition of more complex surgical skills. Human factors in surgery is an important component of surgical training, and the benefit gained from the panoramic view of VR technology could also be an area of future research. Finally, the ultimate goal of any form of surgical education is the ability to transfer those skills taught in a simulated setting to the operating theatre environment. A further study could identify whether the use of VR 360-degree video teaching improved the ability to perform these basic surgical skills in the operative setting.

4.5. Conclusion

This study demonstrates that 360-degree VR video can enhance knot tying skills acquisition both as a standalone video and when supplemented with traditional teaching. It also has the potential to enhance other areas of surgical training including the acquisition of other surgical skills taught on the Royal College of Surgeons, England, (RCSEng) Basic Surgical Skills (BSS) course.

Ethical approval

No ethical approval required however informed consent from all participants involved was gained in our study.

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Author contribution

Design: Sutharsan Yoganathan, David A Finch Ed Parkin.

Statistical analysis: Ed Parkin.

Manuscript writing: Sutharsan Yoganathan, David A Finch, Ed Parkin.

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Final approval of manuscript: All authors.

Conflicts of interest

No conflict of interest.

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Declaration of interest

None.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ijsu.2018.04.002.

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