The first worldwide use and evaluation of Augmented Reality (AR) in "Patient Information Leaflets" in Plastic Surgery

Steven Lo [1,2,3] and Paul Chapman [4]

Author Affiliations

1) Canniesburn Plastic Surgery Unit, Glasgow Royal Infirmary

2) College of Medical, Veterinary and Life Sciences, University of Glasgow

3) Translational Research Centre, Kaohsiung Medical University

4) School of Simulation and Visualisation, The Glasgow School of Art

Corresponding Author:

Steven Lo

Canniesburn Regional Plastic Surgery and Burns Unit, Glasgow Royal Infirmary, Glasgow, G4 0SF

Tel: 0141 211 4000 ext 24475, Steven.lo@nhs.net

Meetings

This work was presented at a Scottish Sarcoma Network (Glasgow Centre) special study day on 6th March 2019 at the School of Simulation and Visualisation, Glasgow School of Art, with representatives from Sarcoma UK, Beatson Cancer Charity and the BBC.

Traditional patient information leaflets inadequately convey medical information due to poor literacy levels: 16-27% of UK population have the lowest adult literacy level [1] and 40% the lowest *"Health literacy"* level (ability to obtain, understand, act on, and communicate health information) [2]. It was hypothesised that an entirely visual approach, such as AR, may obviate literacy problems by facilitating comprehension of complex 3 dimensional concepts integral to reconstructive surgery. We report the first Augmented Reality (AR) in Patient Information Leaflets in Plastic Surgery. To our knowledge we are among the first in the world to develop, implement, and evaluate an AR patient information leaflet in any specialty.

Developed for sarcoma surgery, the AR patient leaflet cantered around a prototypical leg sarcoma. A storyboard takes patients through tumour resection, reconstruction, and the potential post-operative outcomes. Input from specialist nurses, sarcoma patients, and clinicians during a Scottish Sarcoma Network Special Study day in March 2019 informed the final content **(Figure 1)**. When viewed by smartphone camera (free software download: HP Reveal Studio, HP Palo Alto, California USA), photos in the AR leaflet automatically trigger additional content display without need for QR codes or internet connectivity:

1) Sequential tumour resection **(Figure 2)**
2) 3D model animation of ALT flap **(supplementary video 1)**
3) Sequential flap reconstruction
4) Post-operative gait video **(supplementary video 2)**
5) Logo of Beatson Cancer Charity - automatically opens the Beatson Cancer Charity homepage **(supplementary video 3).**

A 3D ALT flap model was developed using Bodyparts3D (Research Organization of Information and Systems Database Center for Life Science, Japan) and custom anatomical data [4]. Leaflet evaluation by 14 consecutive lower limb sarcoma patients was exempted from ethics approval by Greater Glasgow and Clyde NHS Research Office. AR leaflets were compared with pooled data from traditional information sources (Sarcoma UK website patient leaflets (6), self-directed internet searches (5), generic sarcoma patient leaflets (5); some patients used >1 source). The Mental Effort Rating Scale evaluated perceived difficulty of comprehension (or extrinsic cognitive load) [3], as a key outcome measure in comparison to traditional information sources. Patient satisfaction was assessed

by Likert Scale (1 was very, very satisfied and 9 very, very dissatisfied). Statistical analysis performed with Social Science Statistics, 2019.

AR leaflets were rated as 1.57 (very, very low mental effort), traditional information sources as 6.36 (high mental effort) [Unpaired t-test $p<0.0001$]. Likert-scale satisfaction was 1.43, indicating a very, very high satisfaction. When asked *"Do you think the AR leaflet would make you less anxious about surgery?"*, 12/14 (86%) patients responded 'yes'. When asked *"Would you think other patients would like to have a similar AR leaflet before surgery"* and *"Would you like to see further AR leaflets to be developed in the future?",* 100% responded "yes". No correlation was found between age or educational level and Mental Effort Rating Scale scores for AR patient leaflet (data not shown). Subjective feedback analysis found that self-directed internet searches had too much unfocussed information: *" (I) didn't want to Google as may end up with all sorts"* and *"(there is) good and bad stuff on the internet, don't know what you're looking at".* All patients felt the visual content in AR leaflets helped their understanding: *"incredible…that would have made a flap easier to understand", "tremendous… good way of explaining things to my family", "so much better seeing the pictures, gives an idea in your head", and "helpful for others with dyslexia".* Traditional patient leaflets were often difficult to comprehend: *"(I) didn't fully understand the sarcoma leaflets", "couldn't take information in from leaflets".* Feedback recommended adding simple instructions on the leaflet, however the AR leaflet is intended for use by the clinician in clinic, and to be so simple that no instructions are required once software is downloaded to the patient's smartphone (ie *point and shoot* without technical expertise, menus, or website addresses). All patients desired an actual paper leaflet for reassurance, preferring something physical show their family rather than direction to a website or video.

This study demonstrates significant reduction in extraneous cognitive load (mental effort required to understand a topic) with AR patient leaflets compared to traditional information sources ($p<0.0001$). AR visualisation may make inherently difficult topics (intrinsic cognitive load), such as reconstructive surgery, easier to understand and process. Significant learning advantages exist over traditional leaflets or web-based videos, including facilitating patient control, interactivity, and game-based learning. All contribute to increased motivation, comprehension, and enthusiasm in the learning process [5]. AR leaflets reduced anxiety (86% patients), and scored very highly for patient satisfaction

with information, which is notable given increasing evidence of strong independent determination of overall health outcomes.

This study provided impetus for investment in concurrent development of other AR leaflets across the breadth of plastic surgery, and non-plastic surgery specialties. Chief Scientist Office (CSO, Scotland) funding was recruited to aid development of improved, free, fully interactive 3D AR patient information leaflets and a downloadable app. Ethical approval is in place for a randomised controlled trial to quantify the perceived benefits of AR in patient education. Our belief is that AR leaflets will transform and redefine the future Plastic Surgery patient information landscape, empowering patients and bridging the health literacy gap.

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Conflict of Interest Statement

None

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Figure Legends

Figure 1: Augmented Reality patient information leaflet.

All the pictures in this leaflet trigger additional content when a smartphone camera is pointed at the 'target' photos. For example, when a smartphone is pointed at the last photo of the patient walking, a video of the patient actually walking appears in real time on the smartphone as if it were playing on the pages of the leaflet.

Figure 2: Photo of patient information leaflet in use.

This is the first photo in the patient leaflet from Figure 1. A. Smartphone camera is pointed at the "target" picture of a leg. B. This triggers the additional AR content which shows the tumour resection C. The tumour resection floats above the page, and an endoprosthesis can be seen for bone reconstruction.

Supplementary video 1: AR patient leaflet in use

The AR patient leaflet in use, showing the 3D model of the free ALT flap in the thigh and surrounding muscles

Supplementary video 2: Post-operative Gait Video

The AR patient leaflet in use: this shows a post-operative gait video of a patient with a lower limb sarcoma flap reconstruction

Supplementary video 3: AR target takes user directly to website

AR patient leaflet in use: the logo of the Beatson Cancer Charity (who part-funded this study) was used as an AR target. When the smartphone camera 'looked' at this target, this automatically takes the user to the Beatson Cancer Charity homepage without the need to type in a website address or QR codes.