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Research article

Robot-assisted surgical ward rounds: virtually always there

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ABSTRACT

Background While an explosion in technological sophistication has revolutionised surgery within the operating theatre, delivery of surgical ward-based care has seen little innovation. Use of telepresence allowing offsite clinicians communicate with patients has been largely restricted to outpatient settings or use of complex, expensive and static devices. We designed a prospective study ascertaining feasibility and face validity of a remotely controlled mobile audiovisual drone (LUCY) to access inpatients. This device is, uniquely, lightweight, freely mobile and emulates 'human' interaction by swiveling and adjusting height to patients' eye-level.

Methods Robot-assisted ward rounds (RASWRs) were conducted over 3 months. A remotely located consultant surgeon communicated with patients/bedside teams via encrypted audiovisual telepresence robot (DoubleRobotics, Burlingame, CA). Likert-scale satisfaction questionnaires, incorporating free-text sections for mixed-methods data collection, were disseminated to patient and staff volunteers following RASWRs. The same cohort completed a linked questionnaire following conventional (gold-standard) rounds, acting as a control group. Data were paired and non-parametric analysis was performed.

Results RASWRs are feasible (>90% completed without technical difficulty). The RASWR (n = 52 observations) demonstrated face validity with strong correlations ($r > 0.7$; Spearman, p-value < 0.05) between robotic and conventional ward rounds among patients and staff on core themes, including dignity/confidentiality/communication/satisfaction with management plan. Patients (96.08%, n = 25) agreed RASWR were a satisfactory alternative when consultant physical presence was not possible. There was acceptance of nursing/non-consultant hospital doctor cohort [100% (n = 11) willing to regularly partake in RASWR].

Conclusion RASWRs receive high levels of patient and staff acceptance, and offer a valid alternative to conventional ward rounds when a consultant cannot be physically present.

Keywords: robot, telepresence, telecommunication, ward rounds, surgical care, inpatient, novel, patient acceptability

INTRODUCTION

The ward round is a long standing and fundamental feature of inpatient care; its historical existence documented as far back as 1660.[1] A 'complex clinical process', the ward round remains 'critical to providing high-quality, safe care for patients in a timely, relevant manner'. Astonishingly, however, the surgical ward round is a model that has undergone relatively little scrutiny and minimal augmentation since its advent. In fact, it could be said that the 'once inviolable' ward round has 'suffered a gradual and barely noticible decline'.[2] Although once the 'cornerstone of hospital care',[3] in the current climate of ever-increasing procedural and outpatient commitments, the ward round is now an exercise easily encroached upon. The reverence for the early 19th century London surgical ward rounds of Sir Astley Cooper, who circulated the beds of Guys Hospital London accompanied by 'hundreds of students…listening with almost breathless anxiety'[4] has dwindled, and the inpatient round is now often a perfunctory exercise which has failed to be 'adapted to suit a continually evolving, complex system'.[2]

While the past century has seen a technological revolution of surgical practice within the operating theatre, the delivery of ward-based care to surgical patients has been subject to minimal investment or innovation, and continues to 'lack recognition as an important area for scientifically conducted research'.[5] In fact, the UK Health Research Analysis of 2014 reveals a reduction in funding for health service research, incorporating evaluation of inpatient care.[6] This is an alarming reality, given the growing body of data highlighting the pivotal role of perioperative care in determining surgical outcomes.[7] Recent research correlates poor quality surgical ward rounds with up to six fold increases in post-operative morbidity,[8] likely related to the 'failure to rescue' concept identified by Silber in the 1990s.[9] Yet, we have been failing to explore opportunities to enhance patient care at the ward level. Only in the past 5 years has the surgical ward round emerged as a research focus of any description, with the welcome developments of ward round checklists[10–12] and of ward round simulation in education.[13–15] Somewhat ironically, given the profound technological basis of advances within the operating theatre and the presumed predilection of the surgeon for such new 'toys', there has been minimal application of technology to surgical ward rounds.

One innovative area of development with potential application to surgical ward rounds is that of telepresence. We have come a long way from the 1870s appearance of Alexander Graham Bell's now barely recognisable telephone.[16] The rapidly increasing sophistication of technology has allowed the evolution of telepresence as we know it, 'a sensation of being elsewhere, created by virtual reality technology'.[17] Since the concept of modern telepresence was defined by Cisco in 2005,[18] there has been increasing recognition of the potential utility of telepresence in a variety of settings, from classroom and office to manufacturing industries. Compared to face-to-face interactions in psychological experiments, audio-visual conferencing techniques have been shown to achieve almost equivalent levels of trust between interacting parties, although the process of establishing trust may be slightly more prolonged.[19] Communication at videoconferences has historically been said to suffer from lack of subtle listener feedback secondary to delayed transmission and poor quality image display;[20] however, increasing sophistication of technology likely diminishes this issue. Telecommunication interactions may also comprise a greater formality than face-to-face encounters,[20] although this has not been reported in the field of medicine, possibly as doctor–patient interactions are inherently formal via any modality. Walther's social information processing theory suggests that adaptation of parties involved in computer-mediated communication, even in the absence of audio-visual signals, may result ultimately in 'normal' interpersonal interactions.[21]

Several medical specialties have employed the use of visual telecommmunciation, allowing an offsite clinician to effectively assess and communicate with patients. Staff and patient acceptance, validity and cost-effectiveness of robotic presence have been widely demonstrated in the intensive care unit (ICU) setting.[22–24] Telemedicine has also been successfully utilised within the field of stroke medicine,[25–27] palliative care,[28] neonatology,[29] and remote outreach medicine,[30] as well as in the ward-based and post-operative care of orthopaedic[31] and urology[32] patients. Within general surgery, successful employment of telemedicine in the outpatient setting has been demonstrated,[33] and pilot trials of older models of robotic telepresence devices have been conducted in the inpatient setting.[34] All of these endeavours are in the context of sky-rocketing usage of similar technology on a personal level, with surveys revealing 70% of the overall Irish population and 90% of the UK population aged 16–24 owning smartphones in 2015.[35,36]

In an era of ever-increasing demands on health services, conflict of clinical commitments is ubiquitous, and it is frequently difficult for senior surgical team members to maintain a presence on the ward. We contemplated the potential role of technology in ameliorating this. We postulated that telepresence could be successfully incorporated into surgical inpatient care, through its utilisation on ward rounds and set out to investigate feasibility and face validity – the effectiveness of the technology in addressing fundamental ward round aims – of robot-assisted surgical wards rounds (RASWRs). Furthermore, we aimed to evaluate the technology in more depth by assessing patient perceptions of telecommunication interactions in comparison to face-to-face physician encounters. A final objective was to explore staff satisfaction.

METHODS

Study design

A prospective case-control study was designed, with robot-assisted ward rounds (RASWRs) conducted via telecommunication compared against control sample (conventional surgical ward rounds). Ethical permission was obtained from the Hospital Research Ethics Committee. An opportunistic sampling strategy was employed. All the current inpatients on

the day of a RASWR, who were admitted on level-one surgical/mixed wards with any clinical condition resulting in surgical admission, were invited to participate. Exclusion criteria were inability to speak fluent English, lack of capacity to consent and current High Dependency Unit/Intensive Care Unit (HDU/ICU) admission. RASWRs were conducted once–twice per week over 3 months. A morning and evening ward round is conducted daily in our centre. On the days, an RASWR was conducted, which replaced the conventional morning ward round.

Technology

The Double telepresence robot (DoubleRobotics, Burlingame, CA, 2013) was selected as a mobile and cost-effective device. The device comprises an iPad (Apple, California) stand mounted via a telescopic metal rod onto a cylindrical base with wheels. An iPad is inserted into the stand. Double software allows a distant user to connect to this iPad via an IOS app on another Apple device or PC Chrome browser, with projection of the user's visual image and transmission of voice via the iPad. The remote user has visualisation of surroundings via the iPad's inbuilt front-facing camera, with a provided wide-angle conversion lens enhancing the field of view. The wheels and telescopic rod afford mobility. The remote user, via the touchscreen buttons of a distant iPad/iPhone or computer keypad, is enabled to drive, pivot and alter the height of the device, facilitating a dynamic presence. Balance is achieved with an accelerometer and gyroscope, which measure the device's tilt angle and accordingly drive the motors to ensure equilibrium. Video is facilitated via a third party service, OpenTok[37] and based on the WebRTC video standard.[38] An Advanced Encryption Standard (AES) cipher and an Hash-Based Message Authentication Code Secure Hash Algorithim (HMAC-SHA1) system are used to verify encryption and data integrity, respectively. End-to-end video and audio encryptions are ensured by Transport Layer Security, which is compliant with the Health Insurance Portability and Accountability Act (HIPAA) Security Rule for transmission of patient health information over the Internet.[39]

Robot-assisted ward rounds

During RASWRs, a remotely located consultant connected electronically to the robot from a mobile smart-phone device, via 4G data connection or hospital WiFi. The robot was directed, by remote control, on the ward round. The consultant communicated with patients at the bedside via the robot, colloquially dubbed 'Lucy'. The robot was accompanied by at least one non-consultant hospital doctor (NCHD) who communicated observations, investigation results and examination findings.

Data collection

A multi-dimensional patient questionnaire was designed to ascertain patient perceptions of conventional surgical ward rounds and provide control group data (Questionnaire A, Appendix 1). Core themes of communication, dignity/confidentiality, content and duration of ward round interactions were identified and 16 questions formulated within these domains. Responses to each question were based on a five-point adjectival (Likert) rating scale.[40] A free-text box for overall impressions was included.

A second questionnaire was designed for dissemination following an RASWR was designed. This was an identical replication of Questionnaire A with two additions: a definition of telecommunication rounds in the introductory paragraph for patient understanding and a fifth subsection eliciting patients' overall perspectives of robot-assisted rounds. (Questionnaire B, Appendix 2)

All conventional ward rounds studied were conducted in the morning by a consultant accompanied by several NCHDs and a clinical nurse specialist or staff nurse. RASWRs were also conducted in the morning. These involved one to four NCHDs attending the bedside, accompanied by the Double robot, via which a remote consultant communicated. One of the same two consultants partook in all conventional and RASWRs.

Questionnaires were disseminated immediately following rounds. Patients recorded no identifying features on questionnaires, which were numbered and correlated to a pseudonymised database of basic demographic details. Questionnaires were deposited in a blank envelope at the nurses' station or handed to team members.

Twenty-six patients were recruited and each completed a questionnaire following both a conventional and RASWR.

A bespoke questionnaire (Questionnaire C, Appendix 3) was created to interrogate staff perceptions of RASWRs. This was disseminated to nursing staff and NCHDs (postgraduate years 1–10). All staff responders had participated in ≥2 RASWRs.

Timing

A small sample of conventional and RASWRs were timed according to overall duration. Findings suggested that RASWR took approximately 20 minutes longer than conventional ward rounds, due to slower movements between patient rooms and between wards. Time spent at the bedside was comparable. However, given the number of confounding variables, such as number, location and complexity of patients and the signal strength in the vicinity of the remote user directing the robot, it was felt that timing would not be an appropriate outcome measure outside of a non-randomised blinded study, and it was not routinely recorded for analysis.

Data and statistical analysis

Data were collected and analysed. Feasibility was assessed by recording the proportion of RASWRs successfully conducted. Patient data collated from Likert-scale responses were paired and analysed using the non-parametric methodology. Spearman's rank-order correlation was used to compare associations of patient responses between conventional and RASWRs. Prism GraphPad version 7.0 was used for statistical calculations. Qualitative data from patient feedback provided in free-text boxes was coded and evaluated by thematic analysis.[41]

RESULTS

Demographics

Fifty-six patient surveys were disseminated and 52 returned completed (response rate 92.86%, paired data = 26). All

patients invited to participate in RASWR agreed. All inpatients on level one wards on the days RASWRs were conducted participated in a telecommunication interaction (total *n* = 32). However, due to the high turnover of surgical inpatients, not all of these patients were also seen on a conventional ward round at which one of the researchers was present to disseminate a questionnaire. Only patients likely to experience both forms of ward round (*n* = 28) were asked to complete questionnaires, to allow collection of paired data. Patient demographics of the 26 respondents are displayed in Table 1.

Results are presented in Tables 2–7, with free text comments included in Appendix 4.

Feasability

Conduction of robot-assisted surgical ward rounds (RASWR) was feasible, with 24 rounds (92.3%) completed without technical difficulty. Two rounds were terminated prematurely due to inadequate WiFi signal strength resulting in delayed audio-visual transmission; this was resolved with an upgrade to the hospital WiFi system (200-Mb ultrafast broadband connection), providing that the remote consultant was based on a region of reasonable WiFi/4G strength. No ward rounds failed due to mobility issues. Following the WiFi upgrade, the remote consultant independently manoeuvred the device, including for positioning at the bedside. Prior to this, assistance from a team member at the bedside was occasionally used to assist optimal positioning.

Face validity: core theme subanalysis

Content

88.4% of patients (*n* = 23) felt informed of their condition via the robot. This was strongly correlated with patient perceptions of feeling informed on conventional ward rounds (*r* = 0.97; Spearman, *p* = 0.0333). Satisfaction with the management plan formulated on RASWR was high (96.15%, *n* = 25) and strongly correlated with that proposed on conventional ward rounds (*r* = 0.9177, *p* = 0.05).

Communication

Patients reported ability to communicate with their doctor on RASWR (96.15%, *n* = 25). Strong correlations were seen between patient perceptions of understanding the consultant communicating via the robot versus in person (*r* = 0.921, *p* = 0.0667).

Dignity and confidentiality

Maintenance of confidentiality and preservation of dignity were perceived similarly by patients between conventional

Table 1 Respondent demographics

Respondent	Age	Gender (F/M)	Post operative? (Y/N)	Status/diagnosis
1	46	F	Y	Transfer – subacute anastomotic leak
2	49	F	N	Splenic infarct
3	70	M	N	Acute pancreatitis
4	50	F	Y	Elective ileostomy reversal
5	61	M	N	Oesophageal cancer
6	63	M	Y	Sarcoma of abdominal wall
7	38	F	N	Choledocholithiasis – post ERCP
8	73	F	Y	Post open cholecystectomy (gallbladder adenoma)
9	31	F	N	Choledocholithiasis
10	50	M	N	Complicated chronic pancreatitis
11	22	M	Y	Post laparoscopic appendicectomy
12	63	F	N	Acute cholecystitis
13	64	F	N	Post TACE (metastatic GIST)
14	27	F	N	Acute on chronic pancreatitis
15	80	F	N	Adhesional small bowel obstruction
16	68	F	Y	Post Heller's myotomy (achalasia)
17	83	F	N	Pre-ERCP (choledocholithiasis)
18	69	M	Y	Post laparotomy (strangulated abdominal hernia)
19	69	M	Y	Post trans-hiatal oesophagectomy
20	84	F	N	Transfer – Iatrogenic oesophageal perforation
21	42	M	N	Retroperitoneal sarcoma
22	75	F	N	Oesophageal cancer (unresectable)
23	42	M	N	Severe acute pancreatitis
24	70	M	N	Upper GI bleed (duodenal ulcer)
25	67	M	N	Post distal gastrectomy (high grade dysplasia)
26	39	F	N	Post laparotomy & small bowel resection (traumatic lumbar hernia)

ERCP = endoscopic retrograde cholangiopancreatography; GI = gastrointestinal; GIST = gastrointestinal stromal tumour; TACE = transcatheter arterial chemoembolization. Median age 63 years (22–83). Male = 42.3%, Female = 57% and Post operative = 27% (*n* = 7)

Table 2 Results (ward round communication)

n = 26 (paired of 52 surveys)		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Correlation *r* (Spearman)	Correlation *p* value
Q1 – Could you see your doctor?	a. Robot	20 (76.9%)	6 (23.07%)	0	0	0	1	0.05
	b. Conventional	19 (73.07%)	7 (26.92%)	0	0	0		
Q2 – Could you communicate with your doctor?	a. Robot	18 (69.23%)	7 (26.92%)	1 (3.85%)	0	0	0.9177	0.05
	b. Conventional	20 (76.92%)	6 (23.07%)	0	0	0		
Q3 – Were you greeted by your doctor and asked about your well-being?	a. Robot	22 (84.62%)	3 (11.54%)	1 (3.85%)	0	0	0.9177	0.05
	b. Conventional	22 (84.62%)	4 (15.38%)	0	0	0		
Q4 – Did you understand what the doctor said to you?	a. Robot	18 (69.23%)	5 (19.23%)	3 (11.54%)	0	0	0.9211	0.0667
	b. Conventional	15 (57.69%)	9 (34.62%)	1 (3.85%)	1 (3.85%)	0		
Q5 – Did you feel you could discuss symptoms/issues bothering you?	a. Robot	15 (57.69%)	9 (34.62%)	2 (7.69%)	0	0	1	0.0167
	b. Conventional	16 (61.54%)	9 (34.62%)	1	0	0		

and robotic ward rounds (r = 0.9; Spearman, p = 0.0167 and r = 0.9, p = 0.05, respectively). Twenty-four patients (92.3%) felt that they could discuss symptoms or issues bothering them on RASWRs. This was similar to the number of patients reporting that they could discuss such symptoms or issues on a conventional ward round, with a statistically strong correlation observed (r = 1 and p = 0.0167).

Timing

The duration of the bedside consult was seen as appropriate by 92.3% of patients (n = 24).

Patient acceptability

Overall 25 patients (96.1%) agreed that robotic ward rounds were a satisfactory solution when a consultant could not be

Table 3 Results (ward round content)

n = 26 (paired of 52 surveys)		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Correlation *r* (Spearman)	Correlation *p* value
Q8 – Did the team effectively communicate your vital signs and test results to the senior doctor?	a. Robot	18 (69.23%)	6 (23.07%)	2 (7.69%)	0	0	1	0.0167
	b. Conventional	15 (57.69%)	9 (34.62%)	2 (7.69%)	0	0		
Q9 – Did the team examine you appropriately and communicate the findings to the senior doctor?	a. Robot	16 (61.54%)	5 (19.23%)	3 (11.54%)	2 (7.69%)	0	1	0.0167
	b. Conventional	15 (57.69%)	9 (34.62%)	1 (3.85%)	1 (3.85%)	0		
Q10 – Did the doctor inform you of your condition?	a. Robot	17 (65.38%)	6 (23.07%)	3 (11.54%)	0	0	0.9747	0.0334
	b. Conventional	16 (61.54%)	7 (26.92%)	2 (7.69%)	1 (3.85%)	0		
Q11 – Were you satisfied with the management plan?	a. Robot	16 (61.54%)	9 (34.62%)	1 (3.85%)	0	0	0.9177	0.05
	b. Conventional	16 (61.54%)	10 (38.46%)	0	0	0		
Q12 – Did the doctors answer your questions?	a. Robot	15 (57.69%)	10 (38.46%)	1 (3.85%)	0	0	1	0.167
	b. Conventional	16 (61.54%)	9 (34.62%)	1 (3.85%)	0	0		

Table 4 Results (dignity & confidentiality)

n = 26 (paired of 52 surveys)		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Correlation *r* (Spearman)	Correlation *p* value
Q6 – Did you feel the doctors maintained your confidentiality on the ward round?	a. Robot	15 (57.69%)	8 (30.77%)	3 (11.54%)	0	0	1	0.167
	b. Conventional	15 (57.69%)	10 (38.46%)	1 (3.85%)	0	0		
Q7 – Was your dignity preserved on the ward round?	a. Robot	16 (61.54%)	10 (38.46%)	0	0	0	1	0.05
	b. Conventional	17 (65.38%)	9 (34.62%)	0	0	0		

physically present. One patient felt neutrally, no patients disagreed.

Patient acceptability: qualitative results

Eleven patients elected to provide additional feedback in the free-text boxes included in the questionnaire. Thematic analysis revealed emergence of four key themes.

Recognition of utility

The majority of responses revealed patient awareness of the potential utility of telepresence on surgical ward rounds. Patients described the robot as 'a very welcome alternative' and 'a very useful aid to have' in situations when 'the doctor is unable to attend ward rounds' and 'to keep in touch with senior doctors who may not always be around'. The robot was seen as something 'very handy and safe', which can be 'really helpful…for both [doctor and patient]'.

Familiarisation

Patients identified the journey of accustomisation with a new technology, which can 'initially [appear] surreal'. Patients appeared to experience quite a straightforward process of familiarisation, viewing the robot as 'something that can become quickly established and accepted'.

Acceptance as an adjunct to conventional rounds

While patients expressed acceptance of RASWRs, several patients clarified the role of these as an adjunct to conventional ward rounds. Patients cautioned against the use of robotic technology as a total substitute for physical presence, highlighting 'it is always nice to see the doctor in person' to preserve the 'consultant–patient relationship'. Patients expressed satisfaction with the use of telemedicine 'on occasion when the consultant is not available', as 'a combination of the two [robotic and conventional ward rounds] is ideal'.

Technical concerns

Some areas of technical improvement were identified by patients in the early stages of project conduction. Patients suggested that initially the 'device was a bit far away' and that the volume should be 'turned down'. One patient commented that 'the doctor's voice [may be] amplified, [and] visitors and other ward patients may overhear', but stated 'however this is generally the case [on a conventional ward round] anyway'.

Staff perspectives

Of staff surveyed (nursing staff *n* = 5, NCHDs *n* = 6), 80% of nurses and 100% of NCHDs agreed that communication via the robot with both patient and staff was adequate (Tables 7 and 8). All nursing staff and all NCHDs surveyed felt that they could ask questions they had regarding patient care via the robot. All nursing staff and NCHDs agreed or strongly agreed that robotic ward rounds were a satisfactory solution when a consultant could not be physically present. Eighty percent of nurses and 100% of NCHDs surveyed agreed or strongly agreed that they would be comfortable participating in future RASWRs.

DISCUSSION

The results of our study demonstrate successful integration of a mobile telepresence robot into surgical inpatient care. The current hospital practice of general surgeons frequently involves conflicting demands of inpatient, outpatient and procedural commitments. An additional obligation to deliver supra-elective emergency care is typical. Furthermore, many consultant contracts now incorporate multiple-site appointments. It is therefore an ever-growing challenge for surgeons to maintain presence

Table 5 Results (ward round timing)

n = 26 (paired of 52 surveys)		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Correlation *r* (Spearman)	Correlation *p* value
Q13 – Did you feel the doctors spent an appropriate amount of time with you?	a. Robot	15 (57.69%)	9 (34.62%)	2 (7.69%)	0	0	1	0.05
	b. Conventional	15 (57.69%)	10 (38.46%)	1 (3.85%)	0	0		

Table 6 Results (overall impressions)

n = 26 (paired of 52 surveys)	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Q14 – Satisfactory solution if consultant couldn't be physically present?	21	4	1	0	0
Q15 – Comfortable using in future?	16	5	4	0	1*

*Happy for occassional use.

and make timely clinical decisions on inpatient wards. It is here that telepresence, by enabling a senior doctor to remotely assess a patient while obliged to be elsewhere, can bridge the gap. The Double device used in this study is relatively new to the market and results in the surgical setting have not, to our knowledge, been reported. Lightweight and mobile, Double, is less cumbersome than older models, and significantly less expensive. The current outright purchasing cost for the Double without iPad is $3000 (2017).[42] Alternative models described in the literature are reported as costing $145,000 – $250,000 dollars,[30,43] or being leased at $4000–6000 per month (data 2008–2014).[44]

This study adds to the current literature by demonstrating successful application of telepresence in a mixed-demographic surgical inpatient population, by analysing comparability of RASWR to conventional ward rounds, and by piloting use of an innovative, modern device. We feel that the tremendously greater affordabilty of this telepresence device compared to preceding models make it far more attractive to hospital purchasing authorities and therefore a more accessible and realistic potential addition to surgical units throughout the world. Furthermore, its slim lightweight design and maneouverability facilitate a seamless induction to the ward environment, and overcome challenges with storage of original large, less mobile designs. This model of telepresence robot is unique in its ability to emulate a human interaction by swiveling and adjusting height to allow the remote operator and the patient communicate at eye level. Establishment of good eye contact between parties has been shown to positively influence user satisfaction with video conferencing.[45] We hypothesise that the animate characteristics contribute to the remarkably high patient acceptability of our telepresence robot, colloquially dubbed 'Lucy'. Whilst there has been, perhaps, a lukewarm response to early models of telepresence robot in the non-critical care setting, we believe that the novel and advantageous characteristics of this style of telepresence robot make successful integration into surgical inpatient care an easily achievable reality.

Feasibility

There is a body of literature pertaining to telemedicine consultation in the surgical outpatient setting, using various devices that are portable, but not autonomously mobile.[46–50] Additionally, feasibility of telemedicine in the assessment of trauma patients in A&E[51] and ICU patients[23] has been shown. A small number of studies have demonstrated feasibility of telemedicine in surgical inpatient ward rounds, with the use of a portable tablet[52] and older models of remote presence devices.[31,53,54] Our study ascertains feasibility of using the Double to conduct surgical inpatient ward rounds remotely. The main obstacle to successful conduct was quality of Internet connectivity, as alluded to by other authors.[29,55] This was overcome by a planned upgrade of the hospital WiFi system, and use of 4G on wards with limited WiFi signal. As mentioned in the results section, overall ward round duration was not analysed as an outcome measure. We did observe approximately 20 minutes longer taken to conduct RASWR versus conventional ward rounds on a timed random sample, due to slower transit time between wards. This seems relevant only in situations where patients are admitted on 'outlier' wards distant from the main surgical

Table 7 Results (non-consultant hospital doctors' perspectives)

n = 6	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Q1 – Could you and the patient see the doctor via the robot?	3 (50%)	3 (50%)	0	0	0
Q2 – Could you and the patient communicate with the doctor?	1 (16.67%)	5 (8.34%)	0	0	0
Q3 – Did you feel the patient could discuss any symptoms/issues bothering him/her?	1 (16.67%)	4 (66.67%)	1 (16.67%)	0	0
Q4 – Did the team effectively communciate vital signs/examination findings to the senior doctor?	2 (33.34%)	3 (50%)	1 (16.67%)	0	0
Q5 – Could you ask questions you had relating to patient care?	3 (50%)	3 (50%)	0	0	0
Q6 – Did you feel patient confidentiality was maintained on the ward round?	0	4 (66.67%)	1 (16.67%)	1 (16.67%)	0
Q7 – Was the patient's dignity preserved on the ward round?	1 (16.67%)	3 (50%)	2 (33.34%)	0	0
Q10 – Were you and the patient appropriately informed of the management plan?	2 (33.34%)	3 (50%)	1 (16.67%)	0	0
Q11 – Were you satisfied with the diagnosis and management plan?	2 (33.34%)	4 (66.67%)	0	0	0
Q12 – Do you feel an appropriate amount of time was spent with the patient?	2 (33.34%)	4 (66.67%)	0	0	0
Q14 – Do you think telecommunication ward rounds are a satisfactory solution if the consultant cannot be physically present in the hospital?	3 (50%)	3 (50%)	0	0	0
Q15 – Would you be comfortable with regular telecommunication ward rounds?	3 (50%)	3 (50%)	0	0	0

Table 8 Results (nursing staff perspectives)

n = 5	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Q1 – Could you and the patient see the doctor via the robot?	2 (40%)	3 (60%)	0	0	0
Q2 – Could you and the patient communicate with the doctor?	1 (20%)	3 (60%)	1 (20%)	0	0
Q3 – Did you feel the patient could discuss any symptoms/issues bothering him/her?	0	4 (80%)	1 (20%)	0	0
Q4 – Did the team effectively communicate vital signs/examination findings to the senior doctor?	2 (40%)	3 (60%)	0	0	0
Q5 – Could you ask questions you had relating to patient care?	3 (60%)	2 (40%)	0	0	0
Q6 – Did you feel patient confidentiality was maintained on the ward round?	0	4 (80%)	1 (20%)	0	0
Q7 – Was the patient's dignity preserved on the ward round?	0	5 (100%)	0	0	0
Q10 – Were you and the patient appropriately informed of the management plan?	2 (40%)	3 (60%)	0	0	0
Q11 – Were you satisfied with the diagnosis and management plan?	1 (20%)	4 (80%)	0	0	0
Q12 – Do you feel an appropriate amount of time was spent with the patient?	0	4 (80%)	1 (20%)	0	0
Q14 – Do you think telecommunication ward rounds are a satisfactory solution if the consultant cannot be physically present in the hospital?	4 (80%)	1 (20%)	0	0	0
Q15 – Would you be comfortable with regular telecommunication ward rounds?	1 (20%)	3 (60%)	1 (20%)	0	0

base and would not affect all institutions. Transit time between wards and bays also improved with enhancement of the WiFi system. In any case, we feel that a small additional amount of time taken by an RASWR compared to a conventional ward round is more than negated by the time saving advantages of the technology, namely, by the elimination of travel time and the facilitation of efficient integration of targetted inpatient reviews into short hiatuses in other obligatory activities, such as during theatre turnaround times.

Face validity

Our results revealed communication via the robot to be perceived by patients as satisfactory. This correlates with positive findings of other studies evaluating patient satisfaction with telemedicine communication in the ICU,[56] outpatient[57] and inpatient[31,32] settings. A strong majority of patients reported feeling informed of their condition and that their questions were answered. The strong correlation seen with conventional ward rounds suggests our patient population was equally happy with the medical information provided to them via robotic and conventional ward rounds.

Ability to accurately assess a patient's condition, enabling formulation of an appropriate management plan, is an essential requirement of telecommunication ward rounds. While the inspection component of physical examination performed via visual telecommunication devices has been validated,[58–60] the main limitation of the technology remains the inability of the remote operator to complete full physical examination. We overcame this by a team approach, with an NCHD accompanying the robot and examining where indicated. Patients expressed satisfaction with physical examination, inter-team communication and the management plan formulated. Patient perceptions of their clinical management plan demonstrated statistically strong correlations between robot-assisted and conventional ward rounds. We did not formally assess patient outcomes in this study, although note with interest that telecommunication ward rounds in the urology setting have matched the performance of standard rounds in detecting postoperative complications.[53] We are also encouraged by evidence showing patient length of stay (LOS) is not increased by well-conducted telemedicine interventions; in fact, significant reductions in LOS with telemedicine interventions in the ICU setting have been described.[61] Greatest reduction in LOS is noted in ICU settings with 'direct intervention' approaches where the telemedicine provider proactively makes decisions and communicated to bedside providers, and with strategies incorporating multi-disciplinary team rounding;[62] this is an approach routinely mirrored by conventional and RASWR in our institution. Outside of the ICU setting, benefits of telemedicine in reducing time to senior decision-making resulting in expedited investigation or delivery of definitive care has been described.[63] While one might instinctively have concerns regarding integrity of messages and instructions communicated between staff via a telepresence device, a large study amongst nursing staff in the ICU suggests that telemedicine improves communication and collaboration between senior doctors and nurses, facilitating efficient and effective delivery of patient care.[64] Our results demonstrating positive staff responses and strong agreement on themes of communication reiterate this.

Although perhaps captured within global acceptability ratings, patient perceptions of dignity and confidentiality in the context of telepresence have not been explicitly explored. Our results reveal that our patient cohort to view these variables as equally well maintained on robot-assisted and conventional ward rounds. Furthermore, a strong majority of patients expressed willingness to discuss symptoms or issues bothering them via the robot.

It has been previously shown that patient perceptions of the amount of time devoted to doctor–patient interactions influences patient satisfaction in both outpatient[65] and inpatient[66] settings. The majority of patients in our study were satisfied with the time spent at the bedside.

Patient acceptability

Our findings show high levels of satisfaction with RASWR, and of willingness to participate in robot rounds in the future, in a mixed demographic general surgical inpatient population. This adds to the current literature demonstrating satisfaction with 'telerounding' of orthopaedic patients,[31] of young post-operative urology patients,[32] and of surgical patients in ICU.[56] Our results incorporated a wide age range of patients surveyed, with 42.3% aged greater than 65 years. The positive perceptions of RASWRs across our patient cohort are encouraging in light of recent concerns regarding the usability of telemedicine in geriatric populations.[67] Qualitative data reiterate high levels of patient acceptability. We viewed telecommunication ward rounds as an adjunct to conventional ward rounds, and trialled them as such. Patient responses cautioning against the use of telemedicine as a substitute for consultant physical presence verified this supplemental role of the technology. Useful patient feedback regarding volume and distance of the device was used to tailor subsequent RASWRs.

Staff acceptability

Multiple studies in a variety of ICUs have demonstrated high acceptability of both medical and nursing staff with regard to remote presence technology.[68,69] Our findings demonstrate a similarly positive staff response on general surgical wards. No difference in NCHD acceptance was associated with years of professional experience. All nursing staff studied were acquainted with the remote consultant, having previously met in person. Such an established rapport may enhance ease of telecommunication, as shown by other authors.[70]

Limitations

Questionnaire-based studies, like all methods of data collection, have intrinsic limitations. We attempted to minimise these where possible. We removed double-barrelled and leading questions eliminated technical jargon and explained words such as 'telepresence' according to the literature pertaining to recognition of questionnaire bias.[71] RASWR and conventional questionnaires were standardised with even spacing of the horizontal response format to prevent any potential response from appearing visually dominant. There is a risk of acquiescence bias with Likert-scale questionnaires; however, comparison of RASWR ratings against a conventional ward round control sample and incorporation of a free text box for global opinions were used to mitigate this. There is debate regarding the optimal number of responses in a Likert-scale. We chose a five-point scale with the inclusion of a 'neutral' option, as we felt it gave the most balanced selection choice to patients, and has been shown by other authors not to compromise validity or reliability.[72]

The use of team members as data collectors is another potential source of bias; however, we endeavoured to reduce this by collecting anonymised surveys in blank envelopes from nurses' stations. We did not record whether patients' first inpatient experience was with a robot-assisted or conventional ward round, and randomisation of this was not performed due to varied admission dates and LOSs. It is possible that a primacy effect of preferencing-the 'first is best' phenomenon-played a role.[73]

The study of nursing staff and NCHDs was performed as an interesting secondary outcome. There appeared a trend for NCHDs to be slightly more measured in acceptance of the technology than patients; however, sampling size was small and underpowered to evaluate this.

Future potential

An exciting role for telepresence on surgical rounds has emerged from this study. Furthermore, evolution may allow integration of robotic technology with patient data programmes, permitting transfer of patient observations and test results to the remote operator[74,75] and positioning of individualised devices by the bedsides of unwell patients. The technology also has vast potential in environments such as emergency departments and Acute Surgical Assessment Units (ASUs), and in procedural settings as a supervisory and educational tool.[76]

CONCLUSION

RASWRs were conducted successfully in this study. The results demonstrated comparability to conventional ward rounds across measured parameters of communication, dignity and confidentiality, core content and timing. Amongst surgical inpatients, patient satisfaction with this novel technology was seen across a wide demographic, irrespective of age, gender or surgical diagnosis. There was acceptance of RASWRs by patients as an alternative modality when consultant physical presence unfeasible.

These findings affirm the potential role of telepresence in the surgical inpatient setting. While telepresence is not a replacement for physical patient contact, we believe that RASWR has tremendous capacity to augment both the frequency of doctor–patient interactions and the proportion of interactions overseen by a senior surgeon. In an era characterised by unprecedented complexity of surgical patients and escalating, frequently conflicting, obligations faced by surgeons, we must be resourceful. Telepresence has potential to prove a welcome adjunct on the road forward.

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Pre-registration

No pre-registration exists for the reported studies reported in this article.

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APPENDIX 1

Patient Questionnaire

You have been seen on a ward round where your consultant/senior doctor has not been physically present, but communicated with you and the team via a computer (referred to as a 'telecommunication ward round' below). We are eager to receive your feedback on this concept. We would be grateful if you could honestly complete the following questionnaire relating to different aspects of your experience. Please circle the response to each question that most closely reflects your views. All answers are anonymous.

Communication				
1. Could you see your doctor?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
2. Could you communicate with your doctor?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
3. Were you greeted by your doctor and asked about your wellbeing?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
4. Did you understand what the doctor said to you?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
5. Did you feel you could discuss any symptoms or issues bothering you?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Confidentiality				
6. Did you feel the doctor(s) maintained your confidentiality on the ward round?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
7. Was your dignity preserved on the ward round?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Content				
8. Did the team effectively communicate your vital signs and test results to the consultant/senior doctor?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
9. Did the team effectively communicate your vital signs and test results to the consultant/senior doctor?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
10. Did the doctor inform you of your condition?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
11. Were you satisfied with the management plan?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
12. Did the doctor(s) answer your questions?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Timing				
13. Did you feel the doctors spent an appropriate amount of time with you?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Overall Impressions				
14. Do you think telecommunication ward rounds are a satisfactory solution if your consultant cannot be physically present in the hospital?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
15. If you were admitted to hospital in the future, would you be comfortable with regular telecommunication ward rounds?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree

16. Please list any comments you may have, including concerns or possible areas of improvement:

APPENDIX 2

Patient Questionnaire

We are eager to receive your feedback on our ward rounds. We would be grateful if you could honestly complete the following questionnaire relating to different aspects of your experience. Please circle the response to each question that most closely reflects your views. All responses will be anonymous.

Communication				
1. Could you see your doctor?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
2. Could you communicate with your doctor?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
3. Were you greeted by your doctor and asked about your wellbeing?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
4. Did you understand what the doctor said to you?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
5. Did you feel you could discuss any symptoms or issues bothering you?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Dignity & Confidentiality				
6. Did you feel the doctor(s) maintained your confidentiality on the ward round?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
7. Was your dignity preserved on the ward round?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Content				
8. Did the team effectively communicate your vital signs and test results to the senior doctor?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
9. Did the team examine you appropriately and communicate the findings to the senior doctor?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
10. Did the doctor inform you of your condition?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
11. Were you satisfied with the management plan?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
12. Did the doctors answer your questions?				

Timing				
13. Did you feel the doctors spent an appropriate amount of time with you?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
14. Please list any comments you may have, including concerns or possible areas of improvement:				

APPENDIX 3

Medical/Nursing Staff Questionnaire

We are eager to receive your feedback on our robotic ward rounds. Having participated in two or more of these ward rounds, please could you complete the following questionnaire regarding your impressions of the interaction with the doctor communicating via the robot?

Communication				
1. Could you and the patient see the doctor?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
2. Could you and the patient communicate with the doctor?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
3. Did you feel the patient could discuss and symptoms or issues bothering him/her?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
4. Did the team effectively communicate vital signs/examination findings to the senior doctor?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
5. Could you ask questions you had relating to patient care via the robot?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Dignity & Confidentiality				
6. Did you feel patient confidentiality was maintained on the ward round?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
7. Was the patient's dignity preserved on the ward round?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Content				
8. Were you and the patient appropriately informed of the management plan?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
9. Were you satisfied with the diagnosis and management plan?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Timing				
10. Did you feel an appropriate amount of time was spent with the patient?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Overall Impressions				
11. Do you think telecommunication ward rounds are a satisfactory solution if the consultant cannot be physically present in the hospital?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
12. Would you be comfortable with regular telecommunication ward rounds?				
Strongly agree	Agree	Neutral	Disagree	Strongly disagree
13. Please list any concerns you may have regarding telecommunication ward rounds:				
14. Do you have any further comments to add?				

APPENDIX 4

Patient Free Text Comments by Theme
Convenience/Recognition of Utility
"A very welcome alternative to use if doctor is unable to attend ward rounds"
"A very useful aid to have, to keep in touch with senior doctors who may not always be around if you need to speak to them"
"Really helpful because doctor has so many patients – helpful for both of us."
"It's very handy and safe. Any questions can be asked."
Acceptance
"Initially surreal, I feel it is something that can become quickly established and accepted"
Caution re Replacement of Conventional Rounds/Measured Acceptance
"It is always nice to see doctor in person – a combination of the two would be ideal"
"The concept is useful when on occasion the consultant is not available. But there may never be a relationship if the (consultant and patient) only meet once or twice."
"I would prefer to see the consultant more often than telecommunication, but wouldn't mind occasional use."
Areas for Technical Improvement
"Turn down the volume so the ward can't hear"
"Perhaps re the volume, the patient may be inclined to raise his/her voice, plus because the doctor's voice is amplified visitors and other ward patients may overhear. However, this is generally the case anyway."
"Telecommunication device was a bit far away"

Staff Free Text Comments
"Excellent option when consultant not physically available"
"Great idea"
"High noise levels make privacy difficult even in normal ward rounds"