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Contact tracing using real-time location system (RTLS): a simulation exercise in a tertiary hospital in Singapore

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ABSTRACT

Objective We aim to assess the effectiveness of contact tracing using real-time location system (RTLS) compared with the conventional (electronic medical records (EMRs)) method via an emerging infectious disease (EID) outbreak simulation exercise. The aims of the study are: (1) to compare the time taken to perform contact tracing and list of contacts identified for RTLS versus EMR; (2) to compare manpower and manpower-hours required to perform contact tracing for RTLS versus EMR; and (3) to extrapolate the cost incurred by RTLS versus EMR.

Design Prospective case study.

Setting Sengkang General Hospital, a 1000-bedded public tertiary hospital in Singapore.

Participants 1000 out of 4000 staff wore staff tags in this study.

Interventions A simulation exercise to determine and compare the list of contacts, time taken, manpower and manpower-hours required between RTLS and conventional methods of contact tracing. Cost of both methods were compared.

Primary and secondary outcome measures List of contacts, time taken, manpower required, manpower-hours required and cost incurred.

Results RTLS identified almost three times the number of contacts compared with conventional methods, while achieving that with a 96.2% reduction in time taken, 97.6% reduction in manpower required and 97.5% reduction in manpower-hours required. However, RTLS incurred significant equipment cost and might take many contact tracing episodes before providing economic benefit.

Conclusion Although costly, RTLS is effective in contact tracing. RLTS might not be ready at present time to replace conventional methods, but with further refinement, RTLS has the potential to be the gold standard in contact tracing methods of the future, particularly in the current pandemic.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Detailed quantification of contacts identified and time elapsed/taken by real-time location system and electronic medical record.
- ⇒ Detailed quantification of manpower, manpower hours, manpower cost and equipment cost by both methods.
- ⇒ Lack of validation study/gold standard in identifying true contacts, hence unable to perform statistical analysis nor calculate sensitivity and specificity.
- ⇒ Study based on one simulation exercise in one institution.
- ⇒ Impact and cost savings of halting disease transmission earlier not studied.

INTRODUCTION

Densely populated metropolitan cities like Singapore receiving high volumes of international visitors are highly susceptible to emerging infectious disease (EID) outbreaks as evident by the recent COVID-19 pandemic. As such, Singapore needs to continually strengthen its defences against EID outbreaks.[1] Founded on the experiences of previous outbreaks, Singapore took a 'whole-of-government approach' towards implementing pandemic control measures.[2] To test these measures, the Ministry of Health (MOH) requires all public hospitals to participate every 2 years in a national simulation exercise[1 3] and be validated in the management of an infectious disease case. A key assessment criterion of the exercise is contact tracing.

Contact tracing, a systematic process of identification, assessment and management of people exposed to the disease, is a critical element in containing any outbreak.[4] Current methods of contact tracing involve retrospective review of multiple databases, such as electronic medical records (EMRs) entered by healthcare workers, hospital registration systems capturing patient journeys in the hospital and visitor management systems capturing registered visitors to the hospital. After a preliminary list of potential exposures, also known as contacts, is compiled, individual interviews are carried out to identify any other contacts that were not included by the previous systems. These conventional methods are time consuming, heavily manpower dependent and fail to capture a significant number of contacts.[5] This is because the databases used were not primarily designed to identify contacts between individuals[6] and do not provide enough detail to accurately derive a list of contacts. Failure to trace contacts in a timely and accurate manner can lead to continued transmission of diseases, preventing effective control of EID outbreaks.

Radio frequency identification (RFID) technology, which involves fixed readers receiving signals from small ID tags,[7] is widely used in many industries such as commerce and logistics. Tagged items can be identified, tracked and managed in real time through a centralised database and a compatible device.[7] RFID technology is increasingly being adopted for many uses in healthcare settings such as asset and equipment tracking, staff and patient identification, sensing, intervention, and alerts and triggers.[8] These applications provide improvement in patient safety, reduction in medical errors, time and cost savings and improved medical processes.[8] Another potential application of the RFID technology is a real-time location system (RTLS) allowing tracking of interactions among individuals.[5] The use of RTLS in the inference of contact history between healthcare staff and patients has been studied and validated. The National Centre for Infectious Disease (NCID) in Singapore found that RTLS had a sensitivity of 72.2% and a specificity of 87.7%.[9] An intensive care unit in Taiwan found that RTLS had a sensitivity of 81.4%, specificity of 78.8% and accuracy of 80.7%.[6] An emergency department (ED) in the USA found that RTLS doubled the number of contacts identified compared with EMR review.[5]

To date, few studies have evaluated the manpower and economic impact of contact tracing using RTLS compared with conventional methods. RTLS has been found to be an accurate and effective way to perform contact tracing. However, little is known as to whether the accuracy and efficacy of RTLS provides any manpower and monetary cost savings.

In this study, we aim to assess the effectiveness of contact tracing using RTLS compared with the conventional (EMR) method via an EID outbreak simulation exercise in Sengkang General Hospital (SKH), Singapore. The aims of the study are:

1. To compare the time taken to perform contact tracing and list of contacts identified for RTLS versus EMR.
2. To compare manpower and manpower-hours required to perform contact tracing for RTLS versus EMR.
3. To extrapolate the cost incurred by RTLS versus EMR.

We hypothesised that contact tracing using RTLS would allow us to identify contacts in a timelier and more accurate fashion. We also hypothesised that contact tracing using RTLS would confer benefits in manpower and manpower-hours reduction, translating to cost savings for the hospital.

MATERIALS AND METHODS

Context

This study was held in SKH, a 1000-bed public acute hospital in Singapore with a staff of 4000. This study was conducted in February 2019, at a point when SKH was receiving 3149 admissions and 8172 ED visits per month. The study was conducted during the biennial national simulation exercise on EID outbreaks. In this exercise, a surgical patient with a 3-day inpatient stay was selected as the simulated Middle East respiratory coronavirus index case. This patient was admitted through the ED, underwent surgery in the operating theatre (OT) on day 1 and spent 3 days in an inpatient ward.

Equipment

The RTLS used for contact tracing in our hospital was based on SmartSense Solutions infrastructure and SmartSense RTLS platform provided by Cadi Scientific.[10] Staff tags and patient tags were deployed. The staff tags were additionally equipped with an antenna that captured tag interactions within a 2 m radius of itself. Tag signals were picked up by the campus-wide network of in-ceiling wireless receivers and exciters. Our RTLS was tested and operational prior to the data collection. In this study, 1000 out of 4000 staff wore staff tags. The selected 1000 staff included doctors and nurses working in high risks areas such as the ED and the inpatient wards. The rest of the staff, including the remaining doctors, nurses, allied health professionals, ancillary staff and students were not equipped with staff tags. All patients wore patient tags from registration to discharge. Our RTLS platform captured two forms of contact: (1) tag-to-tag based and (2) location based. A tag-to-tag based contact was registered when any tags (staff or patient) were detected within a 2 m radius of a staff tag for at least a 1 min duration. A location based contact was registered when any tags were detected within the same location for at least a 1 min duration. Location of tags were determined via WiFi triangulation and chokepoint tracking.[7,11]

Measures

A prospective case study was conducted during the biennial national simulation exercise in SKH on 28 February 2019 to determine the list of contacts, time taken, manpower required and manpower-hours required to perform contact tracing via both RTLS and the conventional method of databases review (EMR). The date of the exercise was unannounced, with the contact tracing team activated only at the point of the exercise itself. All staff involved in contact tracing were briefed prior to the exercise to record the amount of time spent on performing the work of contact tracing.

Intervention

During the simulation exercise, two concurrent contact tracing team performed contact tracing—one via conventional method (EMR) and the other via RTLS.

Table 1 Comparison of contact list breakdown identified by real-time location system (RTLS) and electronic medical record (EMR)

Role	RTLS	EMR Tagged	EMR Untagged	Total
Healthcare workers	157	27	110	137
Doctors	8	2	39	41
Nurses	149	25	19	44
Allied health professionals	0	0	11	11
Ancillary staff	0	0	41	41
Patients	69	55	0	55
Visitors	0	0	96	96
Total	226	82	206	288

Table created by authors.

The hospital contact tracing team, which comprised nurse leadership in coordination with hospital infection control, performed contact tracing via conventional methods as per existing hospital contact tracing protocol. First, an activity map of the index case, comprising the journey within the hospital, was derived after reviewing the EMR. Subsequently, a list of contacts comprising healthcare workers, other patients and hospital visitors was compiled via various databases. The EMR identified any healthcare workers who documented their interactions with the patient, the hospital registration system identified other patients who were in the same location as the index case and the visitor management system identified visitors who registered to visit the location of the index case.

Concurrently, the other team generated the activity map and the list of contacts using the RTLS platform. The activity map showed the entire journey within the hospital, depicting each location and the duration the index case visited. The list of contacts was then derived for each of these locations, depicting the time and duration of each staff and patient the index case came in contact with.

Analysis

Between the two methods used for contact tracing, we compared the time taken, manpower required, manpower-hours required and the list of contacts identified. Between the two contact lists, we compared the number of contacts and the roles of these contacts (doctors, nurses, allied health workers, ancillary staff, patients or visitors). As a significant proportion of the existing staff were not equipped with the staff tags at that point of the study, the comparison between the lists was done primarily on staff equipped with the tags. Descriptive statistics were used to compare the two methods.

Patient and public involvement

It was not appropriate or possible to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research.

RESULTS

Simulation exercise

The index case had a length of stay of 3 days and 7 min and visited three main locations in the hospital: ED, OT and inpatient ward. RTLS identified 226 unique contacts, of which there were 157 staff and 69 patients. EMR identified 288 unique contacts, of which 82 (27 staff and 55 patients) were tagged (table 1). For a better comparison of results, untagged staff were excluded, and subsequent comparisons were made using only tagged staff and patients.

Out of a total of 260 unique contacts, RTLS identified 226 while EMR (tagged) identified 82, with an overlap of 48 (table 2 and figure 1). RTLS yielded an additional 178 contacts over the 82 contacts EMR (tagged) yielded, giving an additional 217.1% unique contacts. Out of all the unique contacts, RTLS detected 86.9%, while EMR detected 31.5%.

The comparison is further broken down into the three locations visited by the index case, namely the ED, the OT and the inpatient ward. RTLS yielded the highest increase of 263.3% in unique contacts in the ward and lowest increase of 66.7% in the OT (table 2 and figure 1). Interestingly, RTLS yielded an increase of 870.0% unique staff contacts over EMR in the ED.

Comparing the time taken, manpower and manpower-hours required, RTLS took 0.9 hour, 1 manpower and 0.9 manpower-hours, while EMR took 23.7 hour, 42 manpower and 35.3 manpower-hours (table 3). RTLS provided a 96.2% reduction in time taken, 97.6% reduction in manpower and 97.5% reduction in manpower-hours required. By RTLS, only one staff was required to acquire the activity map and contact list. Conversely, by EMR, two staff from the infection control department were needed to lead the contact tracing efforts, involving 24 additional departments and 40 other staff in the process.

In terms of hospital costs, RTLS required an equipment cost (RTLS platform and staff tags) of $653 594 for the first 3 years to purchase and maintain the system, whereas EMR method required no additional equipment cost. In terms of manpower costs computed over the simulation exercise, RTLS method incurred a manpower cost of $62 per contact tracing episode, whereas EMR method incurred a manpower cost of $2125. We computed the expected expenditure over 3 years to evaluate the long-term cost between RTLS and EMR, as the staff tags had an estimated lifespan of 3 years. We found that at least 317 contact tracing episodes were needed in the 3-year period to obtain cost benefit for RTLS (table 4).

Table 2 Comparison of contact list between RTLS and EMR (tagged) by role only and by location/role

Role	RTLS	EMR (tagged)	RTLS (but not EMR)	Both RTLS and EMR	EMR (but not RTLS)	Total unique contacts	RTLS increase over EMR (%)
Healthcare Workers	157	27	136	21	6	163	503.7
Doctors	8	2	7	1	1	9	350.0
Nurses	149	25	129	20	5	154	516.0
Patients	69	55	42	27	28	97	76.4
Total	226	82	178	48	34	260	217.1
* Detection rate (%)	86.9	31.5				100	175.6
Location/role	RTLS	EMR (Tagged)	RTLS (but not EMR)	Both RTLS & EMR	EMR (but not RTLS)	Total unique contacts	RTLS increase over EMR (%)
Emergency department	114	47	90	24	23	137	191.5
Staff (doctors and nurses)	94	10	87	7	3	97	870.0
Patients	20	37	3	17	20	40	8.1
Operating theatre	12	9	6	6	3	15	66.7
Staff (doctors and nurses)	5	1	4	1	0	5	400.0
Patients	7	8	2	5	3	10	25.0
Ward (inpatient)	101	30	79	22	8	109	263.3
Staff (doctors and nurses)	54	16	41	13	3	57	256.3
Patients	47	14	38	9	5	52	271.4

Table created by authors.
*Detection rate = [(Contacts detected by either methods)/(Total unique contacts)]*100%.
EMR, electronic medical record; RTLS, real-time location system.

DISCUSSION

Summary

Overall, RTLS identified almost three times the number of contacts compared with EMR while achieving that with significantly less time, manpower, manpower-hours and manpower cost. One caveat to RTLS that may be prohibitive to its implementation is its high cost of entry as the equipment cost incurred can be significant and might take many contact tracing episodes to occur before providing economic benefit.

Interpretation

Similar to the study in Mayo Clinic,[5] our study found that RTLS identified more contacts than EMR. Interestingly, RTLS identified an unproportionally large increase of unique contacts in the ED, which was later discovered to be false positive due to off-duty staff keeping their tags in ED lockers. The other RTLS contacts within the ED, the OT and the ward were found to otherwise be largely accurate. They were identified by RTLS but not EMR for reasons such as doctors and nurses reviewing patients other than the index case but physically within proximity to the index case. RTLS also detected nurses who chaperoned patients other than the index case to the OT and came in proximity to the index case. Other instances found patients who were physically within the ED as detected by RTLS but omitted by EMR as they were logged as already 'discharged' within the EMR system. The value proposition of the RTLS is its capability in detecting such contacts that would otherwise be difficult to establish in the current systems.

The study in Taiwan and Singapore found RTLS to have good sensitivity, specificity and accuracy.[6 9] In our study, RTLS proved to be effective in the identification of contacts as it possibly has better sensitivity than EMR as shown by the identification of contacts that went undetected by EMR and better specificity by showing some contacts detected by EMR to be false positives due to the subdivision of locations in the RTLS platform. However, non-compliance to tag charging and wearing proved to limit the effectiveness of RTLS. To circumvent such limitations, more staff education and training can be implemented to emphasise the appropriate usage of staff tags. Future tags designs could also be integrated into existing staff cards, which are required for staff to gain access into hospital compound and staff-restricted areas within the campus, thus resolving some of the compliance issues faced in this study.

During the COVID-19 pandemic, Singapore deployed a Bluetooth-based contact tracing app TraceTogether to augment contact tracing capabilities.[10] A validation study comparing the Bluetooth-based app against RTLS by the NCID in Singapore found that RTLS has a sensitivity of 95.3% as compared with 6.5% for the Bluetooth-based TraceTogether app,[12] suggesting RTLS to be a more effective contact tracing tool in the hospital setting. Despite the better sensitivity, there is still a role for Bluetooth-based

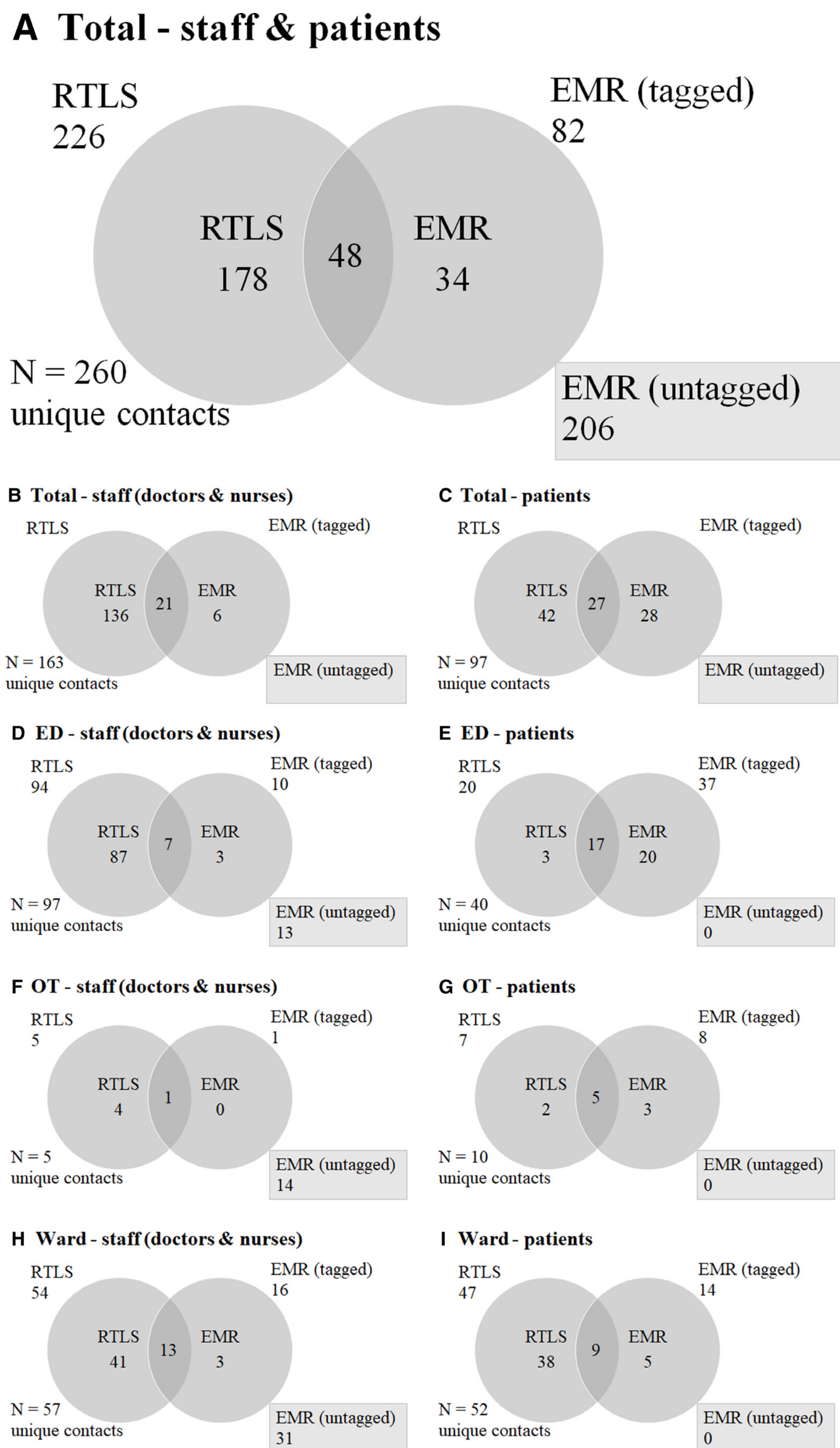

Figure 1 Comparison of RTLS versus EMR (tagged) broken down into: (A) total – staff and patients, (B) total – staff (doctors and nurses), (C) total – patients, (D) ED – staff (doctors and nurses), (E) ED – patients, (F) OT – staff (doctors and nurses), (G) OT – patients, (H) ward – staff (doctors and nurses) and (I) ward – patients. Figure created by authors. EMR, electronic medical record; OT, operating theatre; RTLs, real-time location system.

Table 3 Comparison of time taken, manpower required and manpower-hours required between RTLS and EMR

RTLS				EMR			
Process	*** Elapsed time (h)**	**† Manpower required**	**Manpower-hours required (h)**	**Process**	*** Elapsed time (h)**	**† Manpower required**	**Manpower-hours required (h)**
Index case identified	0	0	0.0	Index case identified	0	0	0.0
Activity map: generate activity map via SmartSense	0.1	1	0.1	Activity map: EMR check (hospital registration system)	0.1	1	0.1
				Activity map: contact OT (OT journey)	0.5	1	0.4
				Activity map: EMR check (EMR)	0.6	1	0.6
				Activity map: contact ED (ED journey)	0.8	1	0.3
Activity map: sort data and fill of MOH activity map template	0.5	1	0.4	Activity map: verify data and fill of MOH activity map template	1.5	2	0.8
Contact list: generate contact list via SmartSense	0.6	1	0.1	Contact list: contact IT department (list of exposed patients)	1.7	1	0.2
				Contact list: email all stakeholders – ED, OT, ward, allied health professionals (AHP - 13 departments), ancillary staff (5 departments)	1.9	1	1.1
				Contact list: contact Automated Visitor Management System (AVMS) (list of exposed visitors)	2.2	2	0.4
				Contact list: sort EMR data (list of exposed patients)	3.9	1	0.2
				Contact list: contact IT department (author list of EMR)	4	1	0.2
				Contact list: sort EMR data (author list of EMR)	7.2	1	0.5
Contact list: review and sort contact tracing data, and fill MOH contact list template	0.9	1	0.3	Contact list: compile data, call and clarify non-response/missing data and fill MOH contact list template	23.7	2	12.0
	* 0.9	† 1	0.9		* 23.7	† 2	16.4

Continued

Table 3 Continued

Downstream departments		Manpower required	Manpower-hours required (h)	Downstream departments		Manpower required	Manpower-hours required (h)
None		0	0.0	Emergency department		1	1.3
				Operating theatre		1	1.0
				Ward 19		1	1.0
				Management information – eHints		1	0.5
				AVMS dept		4	2.5
				Integrated health information systems		2	1.5
				Audiology		1	0.2
				Clinical measurement centre		1	0.1
				Dietetics		1	0.1
				Medical social services		1	0.2
				Occupational therapy		1	0.3
				Pathology		1	0.1
				Pharmacy		2	0.7
				Physiotherapy		3	1.2
				Podiatry		2	0.5
				Psychology		1	0.3
				Radiology		1	0.5
				Respiratory therapy		1	0.8
				Speech Therapy		1	0.2
				Environmental services		6	1.8
				Facilities management and engineering		1	2.0
				General services		2	1.2
				Materials management		1	0.8
				Security		3	0.3
		0	0.0			40	18.9
	*** Elapsed time (h)**	**† Manpower required**	**Manpower-hours required (h)**		*** Elapsed time (h)**	**† Manpower required**	**Manpower-hours required (h)**
Total	* 0.9	† 1	0.9	Total	* 23.7	† 42	35.3
Decrease over EMR (%)	96.2	97.6	97.5				

Table created by authors.
*Elapsed time refers to the amount of time that has passed since the start of the exercise at the point of completion of a process; hence, the total elapsed time is not a simple sum of the previous cells.
†Manpower required is the number of staff it took to perform the process. Many of the processes were performed by the same staff, and hence, the total manpower required is not a simple sum of the previous cells.
ED, emergency department; EMR, electronic medical record; MOH, Ministry of Health; OT, operating theatre; RTLS, real-time location system.

Table 4 Comparison of cost between RTLS and EMR

Cost	RTLS	EMR
* Equipment cost (for first 3 years)	$653 594	$0
† Manpower cost (for each contact tracing episode)	$62	$2125
Case scenarios		
36 contact tracing episodes in 3 years	$655 826	$76 500
156 contact tracing episodes in 3 years	$663 266	$331 500
317 contact tracing episodes in 3 years	$673 248	$673 625

Table created by authors.
*Equipment cost (RTLS)=cost of RTLS platform+cost of staff tags.
†Manpower cost = (manpower-hours of staff 1 * norm cost of staff 1) + (manpower-hours of staff 2 * norm cost of staff 2) + … + (manpower-hours of staff N * norm cost of staff N).

contact tracing apps in the community as RTLS would be challenging to implement.

Since the start of COVID-19 until now, much has evolved on the understanding of the disease transmission. It is now known that COVID-19 spread primarily via oral and respiratory aerosols, as compared with large respiratory droplets contaminated with the virus as initially believed.[13,14] Although RTLS does not possess the fidelity to differentiate between low-risk and high-risk clinical activities, we were able to define RTLS contacts based on the duration of exposure (defined at 1 min in our study). This can also be redefined based on the transmissibility of the specific disease with each subsequent contact tracing episodes.

Aligned with the study in Mayo Clinic that estimated RTLS to take <5 min while EMR to take 30–60 min,[5] our study found RTLS provided significant time, manpower and manpower-hour savings. RTLS can consistently deliver similar results regardless of the index case's length of stay, number of locations visited, number of departments involved (eg, allied health professionals' involvement) or day of contact tracing (weekday vs weekend). Although not specifically measured, contact tracing was swiftly and effectively performed with our RTLS system for 1401 COVID-19 patients in our institution within the first 7 months of the COVID-19 pandemic.[10] With EMR, anecdotal evidence revealed that longer lengths of stay, larger numbers of locations visited, larger numbers of departments involved, as well as contact tracing over a weekend can all result in significant delays in contact tracings. Moreover, should all staff in the hospital be tagged, the objective data provided by RTLS would reduce the subsequent work of verification and interview with each contact. Perhaps, the RTLS platform can also be designed to coordinate with other hospital communication systems to trigger automated text messages or emails to be sent to the affected individuals, further reducing the downstream workload of the contact tracing team.

Our cost computations found that initial investment on the RTLS equipment can prove to be costly and present a significant barrier to entry, requiring about two contact tracing episodes per week for RTLS to warrant the investment, while an average of two contact tracing episodes occurred monthly in our hospital (pre-COVID-19). It is found in other studies that RTLS can be justified in large urban healthcare institutions with diverse patient populations, but not so in small community healthcare institutions.[5] Further studies are required to evaluate and justify the cost of RTLS in Singapore. Alternatively, future studies can look into the cost–benefit analysis of tagging certain groups of the healthcare staff over the others, hence lowering the equipment cost of RTLS.

Privacy concerns can pose significant barrier to adoption and compliance to RTLS tags.[12,15] For privacy reasons, the RTLS data collected is only within the hospital compound and is only stored for a required period (currently set at 3 months). The data obtained retrieved solely for the purposes of contact tracing and is only available to authorised personnel tasked to perform contact tracing work in the hospital.

Limitations

The results of our study are based on one simulation exercise in our institution, hence limiting generalisability. Factors such as index case length of stay, number of locations visited, number of departments involved or the day contact tracing was performed could all influence the results and necessitate further investigations. Despite the absence of any prior notice, the simulation exercise was held within a month of two prior rehearsals. As such, heightened sense of awareness among hospital staff that an exercise was about to occur, coupled with a possible Hawthorne effect of a simulation exercise, could have resulted in shorter than usual response time. As contacts of the index case were not observed prior to contact tracing, there were no definitive means of determining the true positives and negatives of both methods, though the RTLS was tested and deemed operational prior to the data collection. Hence, we were not able to perform any statistical analysis, nor calculate sensitivity or specificity for our data obtained. Therefore, descriptive statistics were used to describe and compare the contacts derived by RTLS and EMR. Also, only 1000 permanent staff deemed working in high-risk areas were tagged. However, our EMR contacts revealed significant untagged populations such as junior doctors on 6 month rotations, allied health professions and ancillary staff providing meals, cleaning and porter services. These groups of people were underrepresented in this study, and their inclusion may result in different contact activities.

Early recognition and mitigation of an EID is paramount in impeding the multiplicative effect of any outbreak, potentially limiting its transmission towards a widespread epidemic. Other studies showed contact tracing to be critical in halting disease transmission,[16] and further studies possibly with computational models can more accurately show the clinical benefits conferred by performing contact tracing with RTLS.

Current cost computations consist of only equipment and manpower costs, without considerations on the economic impact of reducing disease transmission. Future studies taking into account the economic impact of reducing disease transmission, particularly in COVID-19, might show RTLS to confer greater economic benefits than presented in this study.

CONCLUSION

Compared with EMR, we found that RTLS identified contacts in a timelier and more accurate fashion, required fewer manpower and manpower-hours and has the potential to limit disease transmission. Despite the advantages, high equipment cost is incurred with RTLS and might present significant barrier to adoption. RLTS might be at a nascent stage and not be ready to completely replace conventional methods in contact tracing. However, with subsequent cycles of plan–do–study–act[17] and further studies taking into account the economic impact of reducing disease transmission, RTLS has the potential to be the gold standard in contact tracing methods of the future.

This study explicitly examines the time, manpower, manpower-hours, reduction in disease transmission and cost of performing contact tracing between RTLS and other conventional means. Our findings hold implications for hospital administrators and healthcare regulators, especially within the country, to relook at how existing standards of contact tracing can be improved.

*This article was written using Standards for QUality Improvement Reporting Excellence (SQUIRE) guidelines.[18,19]

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Contributors GYN: substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; drafting the work or revising it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. BCO: principal investigator, coauthor and guarantor; substantial contributions to the conception or design of the work; or the acquisition, analysis or interpretation of data for the work; drafting the work or revising it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved; accepts full responsibility for the finished work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

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Patient consent for publication Not applicable.

Ethics approval This study involves human participants, but the SingHealth Centralised Institutional Review Board reviewed and exempted this study. CIRB Ref: 2018/3093.

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