

Implementing web-based ping-pong-type e-communication to enhance staff satisfaction, multidisciplinary cooperation, and clinical effectiveness

A SQUIRE-compliant quality-improving study

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Abstract

Background: Frequent multidisciplinary communication is essential in conducting daily radiotherapy (RT) practice. However, traditional oral or paper-based communication has limitations. E-communication has been suggested, but its effects are still not well demarcated in the field of radiation oncology.

Objects: In our web-based integrated information platform, we constructed a ping-pong-type e-communication function to transfer specific notations among multidisciplinary RT staffs. The purpose was to test whether applying this e-communication can increase effectiveness of multidisciplinary cooperation when compared with oral or paper-based practice. Staff satisfaction and clinical benefits were also demonstrated.

Design and setting: A real-world quality-improving study was conducted in a large center of radiation oncology.

Participants and dataset used: Before and after applying multidisciplinary e-communication (from 2014 to 2015), clinical RT staffs were surveyed for their user experience and satisfaction ($n=23$). For measuring clinical effectiveness, a secondary database of irradiated head and neck cancer patients was re-analyzed for comparing RT toxicities ($n=402$).

Interventions: Applying ping-pong-type multidisciplinary reflective e-communication was the main intervention.

Outcome measures: For measuring staff satisfaction, eight domains were surveyed, such as timeliness, convenience, and completeness. For measuring clinical effectiveness of multidisciplinary cooperation, event rates of severe (i.e., grade 3–4) RT mucositis and dermatitis were recorded.

Results: Overall, when compared with oral communication only, e-communication demonstrated multiple benefits, particularly on notation-review convenience (2.00 ± 1.76 vs 9.19 ± 0.81 ; $P < 0.0001$).

When compared with paper-based practice, e-communication showed statistically significant benefits on all eight domains, especially on notation-review convenience (5.05 ± 2.11 vs 9.19 ± 0.81 ; $P < 0.0001$) and convenience of feedback notation (4.81 ± 1.72 vs 8.76 ± 1.09 ; $P < 0.0001$).

Editor: Maohua Xie.

Author's contribution: Conception or design: S-KH, M-SL, W-YC, W-TT, H-LH, C-LL, D-WL, E-SC, J-CL, H-YL; data acquisition: Y-TS, Y-AL, P-HL, Y-HL; data analysis: F-CH, S-JT; data interpretation: H-YL; drafting: P-HY; revising the work: L-CC, L-WH, H-YL; final approval: S-KH, H-YL.

Pei-Han Yeh and Moon-Sing Lee contribute equally for this work.

Funding/support: The present study is supported by several research grants of our institute Dalin Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation. The funding source fully supported requirement of the present work but did not interact with any of the research process (i.e., design, implementation, and interpretation).

The authors have no conflicts of interest to disclose.

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Medicine (2016) 95:44(e5236)

Received: 15 August 2016 / Received in final form: 28 September 2016 / Accepted: 7 October 2016

<http://dx.doi.org/10.1097/MD.0000000000005236>

Moreover, staff satisfaction was gradually increased from oral (3.57 ± 1.94), paper-based (5.57 ± 2.06), to e-communication (8.76 ± 0.70 ; $P < 0.0001$). Secondary measurement confirmed these observations.

Before and after facilitating multidisciplinary cooperation by using e-communication, severe (i.e., grade 3–4) mucositis and dermatitis were decreased from 21.7% to 10% then to 5.1%.

Conclusions: Replacing oral or paper-based practice with e-communication is useful in facilitating RT multidisciplinary teamwork. Staff satisfaction and clinical effectiveness can be increased.

Abbreviations: EMR = electronic medical record, IMRT = intensity-modulated radiotherapy, rPDCA = re-Plan-Do-Check-Action, RT = radiotherapy, SBAR = Situation-Background-Assessment-Recommendation, SIB = simultaneously integrated boost, SQUIRE = the Standards for Quality Improvement Reporting Excellence, VAS = visual analog scale, VMAT = volumetric-modulated arc therapy.

Keywords: clinical effectiveness, e-communication, quality improvement, radiation oncology, radiotherapy

1. Introduction

1.1. Background

1.1.1. The essence of effective communication in RT daily practice. In modern era, several advanced radiotherapy (RT) techniques are developed, such as intensity-modulated radiotherapy (IMRT)^[1] and volumetric-modulated arc therapy (VMAT).^[2] One common feature of these new developed techniques is the high precision requirement, which is the core element for higher tumor controls and lower treatment toxicities.^[3–5] To achieve this goal, it is crucial to have tight cooperation among RT team members, based on effective interdisciplinary communication through the whole RT treatment course.^[6] For example, information of treatment-specific notations, such as fixation parameters or individual requirements, should be communicated correctly in a real-time manner. However, previous oral or paper-based communication shows low but considerable human-factor limitations.^[7]

1.1.2. Clinical effects of using e-tool in multidisciplinary communication. Many methods have been proved as useful tools for facilitating multidisciplinary communication, such as well-designed training courses^[8,9] and visually based practice.^[10,11] In this regard, a well-designed information system with an e-communication function is useful in enhancing interdisciplinary communication.^[12–14] Good clinical effects have been observed in several fields, such as nursing practice^[15] and intensive care unit.^[16] However, associated evidence is largely lacking in the field of radiation oncology.

One common limitation of interdisciplinary communication is a failure of recording essential contents,^[17] especially in a real-time manner. Thus, the effect of information technology has been reported to be further improved when a structured content was applied, such as Situation-Background-Assessment-Recommendation (SBAR).^[18–20] Moreover, one attractive point of using electronic medical record (EMR) to apply multidisciplinary communication is that information e-tracking and reviewing are easy.^[21]

1.1.3. Problem description: effective communication among team members is essential for multidisciplinary cooperation; however, traditional oral or paper-based communication burdens limitations in clinical practice. Conducting advanced RT techniques requires a tight cooperation among multidisciplinary team members, such as radiation oncologist, medical physicist, oncological nurse, and radiation technologist. Thus, in daily RT practice, effective interdisciplinary communication is essential. However, traditional oral or paper-based communication burdens limitations.

1.1.4. Rationale for applying a web-based e-communication in daily RT practice. To overcome the above problem, we constructed a ping-pong-type reflective e-communication function in our integrated information platform for transferring specific notations before, during, and after RT. Three rationales were as follows:

First, effective communication is essential for enhancing multidisciplinary cooperation in modern RT practice.

Second, traditional oral or paper-based communication burdens limitations in multidisciplinary cooperation in daily RT practice.

Third, several studies supported the role of EMR in enhancing multidisciplinary communication and cooperation.^[12–14] However, evidence is largely lacking to demarcate its effect size in enhancing multidisciplinary RT cooperation and clinical effectiveness.

1.2. Objects, question, and hypothesis

Hence, the main purpose of the present study was to test whether applying e-communication is able to increase staff satisfaction, enhance multidisciplinary cooperation, and then to improve clinical effectiveness—in a real-world RT setting—when compared with traditional oral or paper-based practice.

Our hypothesis was that applying ping-pong-type e-communication is able to increase staff satisfaction, communication effectiveness (such as timeliness, convenience, and completeness), multidisciplinary cooperation, and clinical effectiveness.

1.3. Specific aims

1.3.1. Aim 1. Replacing traditional oral or paper-based practice with e-communication to enhance staff satisfaction and communication efficacy, such as timeliness, convenience, and completeness.

1.3.1.1. Triggered observation/reason/event. Oral or paper-based communication showed limitations in busy daily RT practice. Staff complaints were frequently noted, such as time-wasting and easy-to-miss patterns.

1.3.2. Aim 2. Conducting e-communication for transferring information in a real-time manner among multidisciplinary staffs—before, during, and after RT—to increase multidisciplinary cooperation and clinical effectiveness.

1.3.2.1. Triggered observation/reason/event. In our prior practice, we observed that limitations of traditional oral or paper-based communication resulted in impairments of multidisciplinary cooperation and clinical effectiveness.

No.	Sending time	Events	Sender	Reply / Feedback notation	Reply time	Receiver	Condition	Receiver discipline
1	Dec. 1, 2015	Patient fever today. Please manage this patient with intensive care.	Dr. Lin	Nurse: Got it.	Dec. 1, 2015	De-ID	Managed	Oncology nurse
2	Dec. 1, 2015	Patient fever today. Please manage this patient with intensive care.	Dr. Lin	Radiation technologist: Got it. And, We strengthened body fixation during treatment due to patient agitation.	Dec. 1, 2015	De-ID	Managed	Radiation technologist

Figure 1. Ping-pong-type interdisciplinary communication. Note that the messages are able to be sent from a same information sender (e.g., in Messages No. 1 and No. 2, a radiation oncologist, Dr Lin) to multidisciplinary members, such as oncology nurse and radiation technologist. More notably, the sent information is able to be confirmed and replied by using a ping-pong-type reflective feedback. De-ID = de-identification, No. = number. Note that this figure is English-translated from its Chinese computer-screen-copied counterpart for helping English readers to understand the working interface. Some visual sensation may be different but the content is the same.

2. Methods

2.1. Ethic statement

Analysis and interpretation of the present study obeyed the Helsinki Declaration (written in 1975 and revised in 1983) and the Standards for Quality Improvement Reporting Excellence (SQUIRE) guideline.^[22-24] Privacies of staffs involved were adequately protected.

A formal approval was obtained from our Institution Review Board (IRB; number B10501024). The IRB waived a requirement of written informed consents because only anonymous secondary data were retrospectively analyzed.

2.1.1. Setting and context (participants and dataset used).

From 2014 to 2015, before and after applying e-communication, the present study retrospectively investigated secondary data retrieved from our institute’s accreditation files and quality-improving projects. Staff satisfaction and user experience were analyzed (n=23; but, only 21 questionnaires were considered as effective ones after a formally external validation). And, anonymous RT-toxicity data were also investigated (before e-communication, n=32; early period, n=130; mature period, n=176; total n=338).

Considering department profile, several items were as follows. First, the investigated department was a large, academic, and teaching RT center, with daily undertreatment patients ranged from 80 to 100. Second, as other institutes, multidisciplinary staffs were required for daily RT practice through the treatment course, such as radiation oncologist, medical physicist, radiation technologist, oncological nurse, and administrative staff.

2.2. Interventions

Hence, for overcoming the limitation of traditional oral or paper-based practice, we step-by-step built a new web-based function to conduct ping-pong-type e-communication among multidisciplinary staffs. Several core elements of e-communication were as follows:

First, e-notations were able to be sent from one staff to any of the other staffs. Multiple information receivers were allowed (Figs. 1 and 2).

Second, ping-pong-type e-notation feedback was able to be performed easily, and messages were automatically e-recorded by the system (Figs. 1 and 2).

Third, all auto-recorded e-notations were easily reviewed in the system at any time point. An easy-to-print function was also allowed.

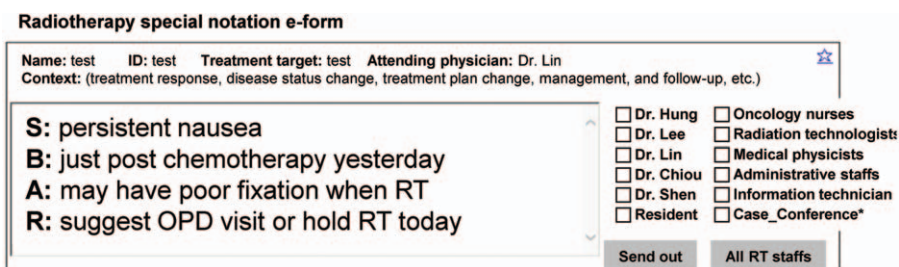


Figure 2. Radiotherapy special notation e-form. The notation e-form was designed for conducting real-time interdisciplinary e-communication among our multidisciplinary RT staffs. Note 1: The right-hand part shows square icons that can be multiply clicked for sending messages to different staffs. Note 2: The left-hand part shows a free text box for documenting messages. In the e-box, we can conduct 2 documenting models: first, free writing for simple events; and, second, structured writing for relatively complex events, such as recommendation of Situation-Background-Assessment-Recommendation (SBAR). Note 3: At the left-upper corner, we designed an empty star. This is a site for marking patients who required high concerns during RT. That is, if indicated, different staffs are able to define these requiring-high-concern patients according to their condition at any time. If it was clicked, the empty star would be red-marked on the user interface. Note 4*: At the right-lower corner, we defined a virtual staff, named “Case_Conference.” This virtual staff represents our weekly case conference. That is, our staffs can also send patient-specific information to case conference for further discussion in an easy real-time way, if indicated. ID=identification, RT=radiotherapy. Note that this figure is English-translated from its Chinese computer-screen-copied counterpart for helping English readers to understand the working interface. Some visual sensation may be different but the content is the same.

Inform status	Name	ID	Confirmed time	WBC	Hgb	PLT
Informed	De-ID	De-ID	Apr. 12, 2016			112
Informed	De-ID	De-ID	Apr. 12, 2016		9.8	
Informed	De-ID	De-ID	Apr. 12, 2016	1.52		

Figure 3. Information-system-based auto-alert function for medical abnormal data. Our integrated information system is able to retrieve laboratory data from our health information system in a real-time manner; more importantly, it can auto-alert our RT staffs in a systemic way. Note 1: The column of “Inform status” shows whether the identified abnormal data are informed to attending physician or not. Note 2: For better visual sensation, we designed our information platform to mark an extremely high or low value with a red-underlying, such as represented WBC value of $1.52 \times 10^3/\mu\text{L}$. De-ID=de-identification, Hgb=hemoglobin (g/dl), ID=identification, PLT=platelet ($\times 103/\mu\text{L}$), WBC=white blood cell ($\times 103/\mu\text{L}$). Note that this figure is English-translated from its Chinese computer-screen-copied counterpart for helping English readers to understand the working interface. Some visual sensation may be different but the content is the same.

Fourth, for messages that involved complex conditions, e-notation was able to be documented in a structured form for providing more effective communication (Fig. 2).

Fifth, systemic alerts for abnormal data were applied as one source of information for further interdisciplinary communication (Fig. 3).

Sixth, other assisted tools, such as physician or nursing orders, were provided as structured e-links for a more user-friendly practice while e-noting (Fig. 4).

Finally, e-notations should be able to be sent to our case conference for further discussion, if indicated (Fig. 2; this is a countermeasure after re-Plan-Do-Check-Action (rPDCA)).

2.2.1. Study of interventions. Using a well-designed information system has been reported as a useful tool for effective communication in multidisciplinary clinical practice.^[12–14] Herein, we selected items that were useful for measuring clinical effects of our e-communication, mainly including surveys for applying timeliness, convenience, and completeness. Structured questionnaire was used for survey. Data were obtained and compared before and after applying e-communication. Internal and external audits for data accuracy were conducted, respectively. Remarkably, two levels of external audits were

conducted for the present study. First, an intramural but extradepartment audit was performed by 3 experienced peers (including 2 medical physicians and 1 biostatistician). Second, formal extramural validations were done by 2 national quality and safety committees, namely, the Taiwan Unimicron and the Joint Commission of Taiwan.

Moreover, we used ping-pong-type reflective e-communication to enhance multidisciplinary cooperation and then to decrease severe RT toxicities, as follows:

First, all RT staffs were allowed to use the e-communication function for transferring individual notations for increasing care quality and patient safety, including radiation oncologist, medical physicist and dosimetrist, oncologic nurse, radiation technologist, and administrative staffs. Non-RT staffs, for example, oncologic registered dietician, were also allowed for interdisciplinary e-communication.

Second, by using e-communication, early e-alarms for mild to moderate RT toxicities (i.e., grade 1–2) were permitted, allowing early intervention of aggressive nursing care.

Third, in addition to receiving early e-alarm from other members, e-communication also allowed automatic e-alerts for regular during-RT nursing care per 5–10 RT fractions, depending on individual condition. According to physician orders, topic

No.	Name	ID	Treatment target	Attending physician	Order time	Dr. order	Nursing order	Patient safety order
1	*De-ID	*De-ID	Head and neck	Dr. Lee	Apr. 12, 2016	Dr. order	Nursing	Patient safety
2	*De-ID	*De-ID	Pelvis	Dr. Lee	Apr. 12, 2016	Dr. order	Nursing	Patient safety
3	*De-ID	*De-ID	Chest	Dr. Lin	Apr. 12, 2016	Dr. order	Nursing	Patient safety
4	*De-ID	*De-ID	Chest	Dr. Lin	Apr. 12, 2016	Dr. order	Nursing	Patient safety

Figure 4. Radiotherapy order e-forms that can be used for assisted tools for enhancing multidisciplinary communication (partial presentation). Multiple order e-forms that are useful for multidisciplinary communication are collected and hyperlinked in a user-friendly e-table. De-ID=de-identification, Dr.=doctor, ID=identification, No.=number, RT=radiotherapy. Note that this figure is English-translated from its Chinese computer-screen-copied counterpart for helping English readers to understand the working interface. Some visual sensation may be different but the content is the same.

agents and mixed oral gargling solutions, including morphine,^[25] were able to be applied individually.

Fourth, at each nursing care, oncologic nurses carefully observed pattern of mucositis and dermatitis, including site, size, and severities.^[26] Detailed nursing notations could be sent to both radiation oncologist and medical physicist via the e-communication. Feedback recommendations were able to be managed promptly.

2.2.2. Measurements for the Aim 1: staff experience and satisfaction. Staff-rated scores for measuring user experience and satisfaction were as follows: terms of communication timeliness, notating convenience, information completeness, feedback convenience, communication confidence, communication effectiveness, review convenience, and overall staff satisfaction for the e-communication. Visual-analog-scale-based (VAS) questionnaire was used to survey subjective feelings of user experience and satisfaction.^[27–29]

2.2.3. Measurements for the Aim 2: incidence of severe RT toxicities. Effective communication has been well-known to be essential in improving cooperation.^[30–32] Thus, in the present study, we selected and analyzed incidence rates of severe RT toxicity (i.e., grade 3–4 mucositis and dermatitis) to measure the enhancing effect of e-communication on multidisciplinary cooperation. The main reason of this selection was that intending to decrease severe RT mucositis and dermatitis requires hard efforts from a tight cooperation among multidisciplinary staffs.^[33]

2.3. Statistical analysis

Data were analyzed and reported according to the reporting guideline, that is, SQUIRE (version 2.0).^[22,23] SPSS (version 12,

IBM SPSS Inc, US)^[34] was used for data analysis. For evaluating intergroup differences of continuous variables, *t*-test was used. Two intramural independent biostatisticians analyzed and validated reported data, as reported previously^[34], namely, Miss Hsu (primary analysis) and Miss Tsai (second check). A *P* value of <0.05 was defined with a statistical significance.

3. Results

3.1. Developing events, involved staffs, and their use amount of e-communication

Developing events were as the following descriptions. First, in late 2013, we started to generate the preliminary framework of the e-communication with our information technician. Second, in early 2014, the pilot structure of the e-communication was established completely and tested preliminarily. Finally, in July, 2014, the established multidisciplinary e-communication was formally online used in our daily RT practice. Note that we used traditional methods for interdisciplinary communication, that is, oral or paper-based communication, before the use of e-communication. After a successful online implementation of e-communication, the used amount of e-notation was large, that is, a record amount of >10,000 was e-communicated in our integrated information platform for around 1200 treated patients in a 1.5-year time period (from July, 2014 to December, 2015), with an average of >8 reflective e-communications per patient.

For constructing the e-communication, 23 staffs were involved, including radiation oncologists (n=5), medical physicists (n=3), radiation dosimetrists (n=1), radiation technologists (n=8), oncological nurses (n=3), administrative staffs (n=2), and oncological nutritionist (n=1; non-RT staff). However, after a

Table 1
Comparison of three tools in conducting interdisciplinary communication.

	Communication tool	Mean	SD	P		
				P1	P2	P3
Timeliness	Oral	6.86	2.65	<0.01	0.20	
	Paper	4.48	1.81			
	E-communication	7.71	1.35			
Notating convenience	Oral	3.10	2.47	<0.001	<0.0001	
	Paper	5.29	2.33			
	E-communication	7.95	1.47			
Information completeness	Oral	3.86	1.93	<0.0001	<0.0001	
	Paper	6.14	1.93			
	E-communication	8.43	1.08			
Feedback convenience	Oral	3.62	2.25	0.02	<0.0001	
	Paper	4.81	1.72			
	E-communication	8.76	1.09			
Communication confidence	Oral	3.67	2.11	<0.0001	<0.0001	
	Paper	6.43	1.66			
	E-communication	8.48	0.68			
Communication effectiveness	Oral	3.95	2.50	<0.01	<0.0001	
	Paper	5.29	2.08			
	E-communication	8.71	0.96			
Review convenience	Oral	2.00	1.76	<0.0001	<0.0001	
	Paper	5.05	2.11			
	E-communication	9.19	0.81			
Overall satisfaction	Oral	3.57	1.94	<0.0001	<0.0001	
	Paper	5.57	2.06			
	E-communication	8.76	0.70			

P1 = oral- versus paper-communication, P2 = oral- versus e-communication, P3 = paper- versus e-communication, SD = standard deviation.

Table 2**The second comparison of effects of e-communication.**

	Communication tool	Mean	SD	P
Timeliness	Paper	4.48	1.81	
	E-communication_1	7.71	1.35	$P1 < 0.0001$
	E-communication_2	7.70	1.35	$P2 < 0.0001$
Notating convenience	Paper	5.29	2.33	
	E-communication_1	7.95	1.47	$P1 < 0.001$
	E-communication_2	8.04	1.52	$P2 < 0.001$
Information completeness	Paper	6.14	1.93	
	E-communication_1	8.43	1.08	$P1 < 0.0001$
	E-communication_2	8.52	1.14	$P2 < 0.0001$
Feedback convenience	Paper	4.81	1.72	
	E-communication_1	8.76	1.09	$P1 < 0.0001$
	E-communication_2	8.78	1.11	$P2 < 0.0001$
Communication confidence	Paper	6.43	1.66	
	E-communication_1	8.48	0.68	$P1 < 0.0001$
	E-communication_2	8.57	0.71	$P2 < 0.0001$
Communication effectiveness	Paper	5.29	2.08	
	E-communication_1	8.71	0.96	$P1 < 0.0001$
	E-communication_2	8.78	0.98	$P2 < 0.0001$
Review convenience	Paper	5.05	2.11	
	E-communication_1	9.19	0.81	$P1 < 0.0001$
	E-communication_2	9.26	0.88	$P2 < 0.0001$
Overall satisfaction	Paper	5.57	2.06	
	E-communication_1	8.76	0.70	$P1 < 0.0001$
	E-communication_2	8.74	0.69	$P2 < 0.0001$

E-communication_1 and paper-based communication were re-noted again from Table 1 for easy comparison with E-communication_2.

E-communication_1, the primary measurement for user experience and satisfaction for the e-communication; E-communication_2, the subsequently secondary measurements.

$P1$ = e-communication_1 versus paper-based communication, $P2$ = e-communication_2 versus paper-based communication, SD = standard deviation.

formally external validation, only 21 questionnaires were considered for data analysis (an effective rate, 91.3% [21/23]).

3.2. Improved aim-specific study endpoints, in terms of clinical effectiveness and staff satisfaction

Aim-specific endpoints were measured at two time-points for data validation: first, 2 weeks after online use of the e-communication function (Table 1); and second, 3 months thereafter (Table 2). Note that the second measurement was conducted after an rPDCA improved event of “adding case-conference as a virtual staff to send patient-safety-related issues for a more extensive discussion.”

As shown in Table 1, when compared with oral or paper-based communication, most aim-specific endpoints showed improved results after implementing e-communication, as follows. First, when compared with oral communication only, e-communication demonstrated multiple benefits, particularly on notation-review convenience (2.00 ± 1.76 vs 9.19 ± 0.81 ; $P < 0.0001$). But, no significant benefit on timeliness was observed (6.86 ± 2.65 vs 7.71 ± 1.35 ; $P = 0.20$). Second, when compared with paper-based communication, e-communication showed statistically significant benefits on all eight domains, especially on notation-review convenience (5.05 ± 2.11 vs 9.19 ± 0.81 ; $P < 0.0001$) and feedback notation (4.81 ± 1.72 vs 8.76 ± 1.09 ; $P < 0.0001$). Third, staff satisfaction was increased gradually from oral (3.57 ± 1.94), paper-based (5.57 ± 2.06), to e-communication (8.76 ± 0.70 ; $P < 0.0001$).

As shown in Table 2, secondly measured data confirmed the above observation. Hence, mainly due to a good clinical utility of the e-communication function, parallel expanding is aggressively ongoing.

3.3. Data e-capture for e-communicating messages is easy, resulting in obvious time saving to make RT treatment documents, for example, RT summary report

Contents of the ping-pong-type e-communication were able to be e-captured for helping to make formal RT documentations. For example, with a help of data capture from e-communication records, average time-saving rate was 74.0% for making a formal RT document (from 25 shortened to 6.5 minus; $P < 0.0001$). Of these, a time-saving rate of 75.0% for making a RT summary report was observed (from 20 to 5 minus; $P < 0.0001$).

3.4. E-communication enhancing multidisciplinary cooperation and then clinical effectiveness: an example of decreasing severe RT dermatitis and mucositis

RT is effective in managing cancers; however, side effects are not uncommon.^[35–37] For example, in managing head and neck cancer patients, severe (i.e., grade 3–4) mucositis or dermatitis is still a problem required to be overcome.^[1] Clinically, severe toxicities may prolong treatment course and impair tumor control. Thus, efforts to decrease incidence of severe RT mucositis and dermatitis are encouraged.

Wishing to decrease severe RT mucositis and dermatitis, a tight cooperation among multidisciplinary staffs is essential. In this regard, we used e-communication to conduct an early alarm. After early alarming, tight multidisciplinary cooperation gradually decreased during-RT severe mucositis and dermatitis: from 21.9% (7/32; before e-communication) down to 10% (13/130; early period) then to 5.1% (9/176; mature period; $P = 0.001$).

3.5. An unexpected benefit of e-communication: internalizing an invisible culture—“documenting anything that may be useful for protecting patients”

In addition to increased staff satisfaction, mainly based on an enhanced convenience and effectiveness of applying e-documentation, we observed that an invisible culture was internalized in our daily RT practice, that is, a habit of “documenting anything that may be useful for protecting patients.” However, this invisible culture cannot be well measured in the present study. Further prospective studies may be required to define its effect size.

4. Discussion

4.1. Summary: key findings, including relevance to rationale and specific aims.

In the present study, the built e-communication function showed multiple clinical benefits, mainly enhancing user experience and staff satisfaction (Table 1). Clinical effectiveness was also improved via a more effective multidisciplinary cooperation. Four observations supported these aim-specific achievements.

First, when compared with oral communication only, e-communication demonstrated multiple benefits, particularly on “convenience for reviewing notation” (2.00 ± 1.76 vs 9.19 ± 0.81 ; $P < 0.0001$). But, on the other hand, no significant benefit on timeliness was observed (6.86 ± 2.65 vs 7.71 ± 1.35 ; $P = 0.20$; *Aim 1*).

Second, when compared with paper-based communication, e-communication showed statistically significant benefits on all eight domains, especially on “convenience for reviewing notation” (5.05 ± 2.11 vs 9.19 ± 0.81 ; $P < 0.0001$) and “applying ping-pong-type feedback” (4.81 ± 1.72 vs 8.76 ± 1.09 ; $P < 0.0001$; *Aim 1*).

Third, staff satisfaction was also increased. As shown in Table 1, when compared with oral (3.57 ± 1.94) or paper-based (5.57 ± 2.06) communication, e-communication showed a relatively higher overall satisfaction (8.76 ± 0.70 ; both $P < 0.0001$; *Aim 1*).

Note that for the above three observations, secondly measured data showed similar findings (Table 2). And, these results were similar to previous reports^[12–14] and suggested that establishing a web-based e-communication function could be considered for enhancing clinical effectiveness in daily RT practice.

Fourth, our system allowed an easy way to perform data e-capture for e-communicating messages, resulting in obvious time saving to make RT summary report (from 20 to 5 minus, with a time-saving rate of 75.0%; $P < 0.0001$).

Fifth, by using e-communication, our multidisciplinary cooperation was enhanced, leading to an increase of clinical effectiveness. For example, for head and neck cancer patients, incidence rates of during-RT severe mucositis and dermatitis were decreased gradually: from 21.9% (7/32; before e-communication) down to 10% (13/130; early period) then to 5.1% (9/176; mature period; $P = 0.001$).

4.2. Interpretation

Using information technology to conduct e-communication has been reported to be useful in clinical practice.^[12–16] Several benefits are noted, such as reducing clinical errors^[15] and avoidable hospitalization.^[13] However, its role is rarely defined in radiation oncology.

Herein, we established a ping-pong-type e-communication system to enhance multidisciplinary communication to facilitate clinical effectiveness, protect patient safety, and to increase staff satisfaction. We observed several clinical benefits of applying e-communication, in terms of timeliness, convenience, and completeness. Moreover, staff satisfaction was also elevated for their daily RT practice.

More notably, by using data e-capture, messages that were documented via the e-communication system were able to increase efficacy of making a RT summary report (from 20 to 5 minus; time-saving rate, 75.0%; $P < 0.0001$). This observation was similar to, or slightly better than, a recent report (68.3%; from 22.4 minus to 7.1 minus).^[38]

In addition, e-communication enhanced our multidisciplinary cooperation and then increased clinical effectiveness, in terms of decreased incidence rates of during-RT severe mucositis and dermatitis: from 21.9% down to 10% then to 5.1% ($P = 0.001$). After e-improvement, our data (VMAT with or without simultaneously integrated boost (SIB)) were better than others' report, for example, $>27.6\%$ (IMRT),^[11] $>22.4\%$ (IMRT plus SIB),^[39] and $>45\%$ (VMAT plus cetuximab).^[40]

4.3. Study strength

First, designing and implementing a ping-pong-type reflective e-communication to enhance multidisciplinary teamwork is the main strength of the present study.

Second, using e-communication has been reported to improve clinical effectiveness and ensure patient safety. Herein, our e-communication function showed multiple clinical benefits. This achievement was mainly due to our user-centered design and aggressive involvement of clinician in the designing process, as recommended by prior studies.^[41,42]

Third, the present study confirmed a large cost-effectiveness of applying web-based e-communication in multidisciplinary clinical care in a context of modern RT department.

4.4. Study limitations

First, user experience is mainly reported from a single RT department. More user experiences should be collected for analysis after further parallel expanding.

Second, though it is still preliminary, for some complicated cases, we also found a limitation of slightly decreasing agreement on care plans between a physician and oncologic nurse, as per previous report.^[43] Thus, in clinical practice, using in-person communication to assist e-communication should be strongly considered in complex situation.

Third, in considering severe RT toxicities of head and neck cancer patients, one limitation is a relatively small case number in before-e-communication period ($n = 32$) than that of early- ($n = 130$) and mature- ($n = 176$) e-communication periods. The reason of this case number discrepancy is that only data that can be validated by external peers are used in the present study. As a result, in the before-e-communication period, only 32 patients were retrospectively allocated because they had intact and validated paper-based RT-toxicity checklists. Other patients who had no RT-toxicity checklists cannot be confidently validated by external peers; thus, these cases were excluded for analysis.

Fourth, though we carefully wrote the current work according to recommendations of the SQUIRE reporting guideline,^[22,23] intrinsic differences between quality-improving studies and formal academic investigations may be still significant, such as

sub-sections (or sub-heading) under Introduction-Material/Method-Result-Analysis-Discussion (IMRAD).^[44,45] However, we would like to note that though these intrinsic differences do exist, a well-validated quality-improving study could be also of value in improving clinical practice similar to formal academic investigations.

Fifth and finally, though validated, the present study did analyze secondary database retrospectively; hence, unobserved variables inevitably exist. As a result, the present data should be carefully interpreted. Further prospective studies may be required to further confirm our observation.

5. Conclusion

Applying ping-pong-type reflective e-communication should be critically considered for increasing staff satisfaction, enhancing multidisciplinary cooperation, and then increasing clinical effectiveness. Further parallel expanding is ongoing.

Acknowledgment

We would like to thank all of our RT staffs. Without your help and feedback of user experience, our e-communication function cannot be reached its current version.

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