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Substitution, delegation or addition? Implications of workforce skill mix on efficiency and interruptions in computed tomography

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Abstract.

Objectives. This study evaluated multiple computed tomography (CT) workforce models to identify any implications on efficiency (length of stay, scan frequency and workforce cost) and scanning radiographer interruptions through substituting or supplementing with a trained CT assistant.

Methods. The study was conducted in a CT unit of a tertiary Queensland hospital and prospectively compared four workforce models, including usual practice: Model 1 used an administrative assistant (AA) and one radiographer; Model 2 substituted a medical imaging assistant (MIA) for the AA; Model 3 was usual practice, consisting of two radiographers; and Model 4 included two radiographers, with a supplemented MIA. Observational data were collected over 7 days per model and were cross-checked against electronic records. Data for interruption type and frequency, as well as scan type and duration, were collected. Annual workforce costs were calculated as measures of efficiency.

Results. Similar scan frequency and parameters (complexity) occurred across all models, averaging 164 scans (interquartile range 160–172 scans) each. The median times from patient arrival to examination completion in Models 1–4 were 47, 35, 46 and 33 min respectively. There were between 34 and 104 interruptions per day across all models, with the ‘assistant role’ fielding the largest proportion. Model 4 demonstrated the highest workforce cost, and Model 2 the lowest.

Conclusion. This study demonstrated that assistant models offer similar patient throughput to usual practice at a reduced cost. Model 2 was the most efficient of all two-staff models (Models 1–3), offering the cheapest workforce, slightly higher throughput and faster examination times. Not surprisingly, the additional staff model (Model 4) offered greater overall examination times and throughput, with fewer interruptions, although workforce cost and possible role ambiguity were both limitations of this model. These findings may assist decision makers in selecting the optimal workforce design for their own individual contexts.

What is known about the topic? Innovative solutions are required to address ongoing health workforce sustainability concerns. Workforce substitution models using trained assistants have demonstrated numerous benefits internationally, with translation to the Australian allied health setting showing promise.
What does this paper add? Building on existing research, this study provides clinical workforce alternatives that maintain patient throughput while offering cost efficiencies. This study also quantified the many daily interruptions that occur within the CT setting, highlighting a potential clinical risk. To the best of our knowledge, this study is the first to empirically test the use of allied health assistants within CT.

What are the implications for practitioners? Role substitution in CT may offer solutions to skills shortages, increasing expenditure and service demand. Incorporating appropriate assistant workforce models can maintain throughput while demonstrating implications for efficiency and interruptions, potentially affecting staff stress and burnout. In addition, the assistant's scope and accepted level of interruptions should be considerations when choosing the most appropriate model.

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Introduction

Innovative responses are required to combat the challenges facing healthcare organisations, including skills shortages, workforce costs and increasing service demand.[1–10] Role redistribution to assistant workforces has been successfully used in various disciplines.[1–3,5–11] One study, using simulated models, found that substituting an assistant for a radiographer can offer substantial cost savings.[12] Despite national calls for allied health assistant (AHA) implementation,[13,14] assistant workforces remain underreported within medical imaging. Medical imaging assistants (MIA) are AHAs specific to medical imaging, performing administrative tasks, restocking and coordination of patient transportation. Training of AHA and MIA roles occurs in-house or via registered training organisations,[7–9,15] with studies demonstrating appropriately trained assistants can substitute Allied health practitioners (AHPs) with basic clinical tasks.[1,2,5–7,9,15] To the best of our knowledge, this study is the first to empirically test the use of MIAs within computed tomography (CT).

Medical imaging consists of a variety of specialist imaging modalities, such as CT. Emergency departments (EDs) in Australia[13] and internationally[16,17] increasingly rely on CT to improve access, efficiency and patient outcomes.[14,17,18] There are many steps in performing clinical CT examinations, including bookings, delivering preparatory instructions or material, protocolling (assigning examination type and requirements), patient prioritisation and coordination. Therefore, inefficiencies within CT can potentially delay diagnosis and treatment.[14,18]

Methods

Objectives

This study explored the efficiency implications of incorporating an assistant workforce within the CT unit servicing an emergency department (CTED). The study was a prospective comparison of multiple workforce models, including usual practice, to measure the efficiency of each. The primary outcome was efficiency, measured as the medical imaging department length of stay (MIDLOS) and patient throughput (i.e. the number of scans performed). Secondary outcomes were workforce model cost and the frequency of interruptions.

Setting

This study was completed within a tertiary hospital in regional Queensland servicing a catchment area in excess of 145 000 km^2.[19] With over 80 000 ED patient presentations during the year of the study, the hospital's ED is among the busiest in Queensland.[20,21] Data from the Radiology Information System (RIS) demonstrated that approximately 12.5% of the hospital's ED presentations were referred for CT imaging during the study period. These referral patterns are consistent with reports from other CTED settings.[14,17,18]

The CTED unit sits within the medical imaging department (MID) of the hospital and is situated directly adjacent to the ED. Although all ED patients are usually scanned within the CTED, the unit contributes to the broader department and hospital in scanning in-patients, intensive care unit (ICU) patients and out-patients.

Within the MID, there is a pool of 10 fully trained CT radiographers, drawn upon to staff three CT scanners, including CTED. At the time of the study, CTED staffing consisted of two radiographers from 0800 to 1700 hours and a nurse, with the radiographers performing both the scanning and administrative roles. A third evening shift radiographer worked on their own from 1700 to 2000 hours. From 2000 to 0800 hours, after-hours imaging was performed by rostered shift radiographers who possessed basic CT training and one fully trained CT radiographer rostered on-call each shift to perform the complex cases. In providing a 24-h on-call service, the CTED radiographer not on-call may subsequently work alone during fatigue leave of the other (minimum safe rest time from last recall). Staff new to the CTED (supernumerary) are trained by existing radiographers, but training was suspended during the study to minimise the potential for confounding.

Participants

Six participants were recruited from existing MID staff for the study: four radiographers, one MIA and one administrative assistant (AA). An expression of interest was posted within the MID for volunteers from relevant staff pools and any oversubscriptions were mitigated using random assignment. Participants were recruited, selected and consented by a member of the research team not employed within the MID. The same radiographers and MIA were rostered across models to reduce intermodel variations, and all were experienced in their substantive roles. The AA and MIA underwent CTED competency refresher training in the weeks before the study, ensuring consistency of skills. Competencies for the 'assistant' duties were developed for assistant training and competency assessment before the study. During the study, one participant was responsible for undertaking hospital patient bookings, scheduling and fielding telephone calls (assistant role), whereas the other was responsible for conducting the scans (radiographer).

Methodology and sequence of events

This prospective observational study used an external observer to record staff movements over four 7-day models during the period October–November 2017. Each model was interspersed

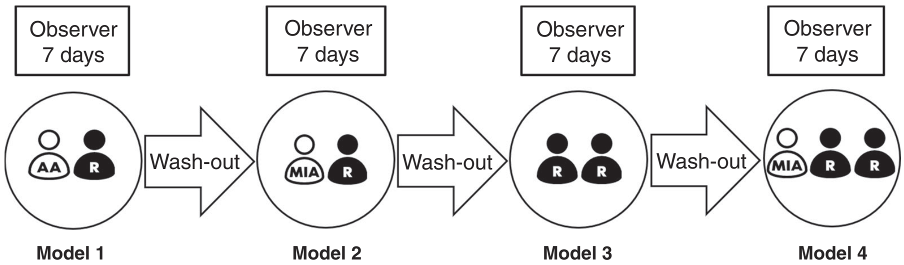

Fig. 1. Schema of the study design. Each model was trialled for 7 consecutive days with a 7-day wash-out period. Model 1 consisted of an administrative assistant (AA) and a radiographer (R); Model 2 consisted of a medical imaging assistant (MIA) and a radiographer; Model 3 consisted of two radiographers (usual practice); and Model 4 consisted of an MIA and two radiographers.

with a 7-day 'wash-out' period, allowing a return to 'business as usual' and preparation to test the next model (Fig. 1).

Model 1 substituted an AA for a radiographer (AA + radiographer) and Model 2 substituted an MIA for a radiographer (MIA + radiographer). Model 3 was usual practice (two radiographers, with one undertaking the 'assistant' role) and Model 4 consisted of an MIA with two radiographers. All models consisted of one registered CT nurse, but the nurse staffing was not a focus of this study and remained as usual practice.

Observation occurred from 0800 to 1700 hours, Monday–Sunday. Data were manually recorded on a specifically developed form and included the number, type and duration of scans and interruptions. These data were later electronically transcribed and then independently verified against the RIS and hospital electronic medical records (EMRs). Furthermore, this study was scheduled to avoid events that knowingly affect ED referrals (e.g. major sports events, holidays, influenza season).

A stopwatch was used by the observer to measure examination times (min). Aspects of the examination time included: (1) order entry, protocolling, booking; (2) patient arrival; (3) start of imaging; and (4) leaving the CT. Each model was evaluated using the MIDLOS, the time difference between the patient arriving in the department and when the examination was finished (ready for reporting). This outcome measure was chosen before the study because it provides a consistent measure, free from factors such as hospital porterage and radiologist staffing, prioritisation and reporting. Order entry time, time to radiologist protocol, time of booking and time to the department were all influenced by confounding factors outside the control of the study.

Interruptions were categorised into three subcategories and the frequency was recorded for each category: (1) protocol interruptions, which were telephone interruptions regarding the radiographer discussing or assigning how the examination is performed; (2) appointment interruptions, which were telephone interruptions during the CT examination for the booking, scheduling or confirming of urgent examinations; and (3) 'issues', which were all other interruptions, mainly urgent face-to-face interactions with the referrer or radiologist to answer queries or to clarify, confirm, review or prioritise cases and patient care. Times were also recorded (min) for order entry, protocolling, booking, patient arrival, start of imaging and leaving the CT. Observed patient throughput was checked against the integrated EMR and RIS data.

Financial efficiency was considered in estimating the annual workforce costs, calculated using the Queensland Health wage rates,[22] and presented as the cumulative participant salaries for each model. Nursing and observer costs were excluded because these were constant throughout all models.

The study sample size was determined by the number of CT examinations performed during the study period (i.e. all scans performed during the observation period for each model were included in the study). Analyses were conducted to examine the significance of differences between the models. First, homogeneity of variance was tested using Levene's test. Descriptive statistics are presented as the mean or median, as appropriate, depending on distribution, and categorical variables are presented as frequency and percentages. The similarity of baseline characteristics was analysed using analysis of variance (ANOVA) for continuous outcomes (per model) and between groups using Bonferroni adjustment. Where data were non-parametric, Kruskal–Wallis tests were performed with a series of Mann–Whitney *U*-tests for post hoc comparison. Categorical variables were analysed using Chi-squared tests.

Ethics

Ethics approval for the study was obtained from the Townsville Hospital and Health Service Human Research Ethics Committee (HREC/17/QTHS/107).

Results

In all, 661 scans were requested with four cancellations, leaving 657 scans for analysis, with similar numbers of scans observed across models (Table 1). Scan profiles across the models were also similar, including 48 scan types, referring area (ED, ICU, in-patient, out-patient), region of the body scanned, contrast media use and the number of phases all considered.

No significant difference was found in the median time (min) from patient arrival to the start of the examination between models ($H = 2.43$, $P = 0.49$). However, there was a significant difference in the median time (min) from arrival to the finish of the examination between the different models ($H = 9.14$, $P = 0.03$; Table 2). Mann–Whitney *U*-tests indicated that the time from arrival to finish was significantly longer in Model 3 than in Model 2 ($P = 0.006$) and Model 4 ($P = 0.008$).

Interruptions to scanning radiographer

An average mean of 445 interruptions occurred per model, ranging from 34 to 104 interruptions per observed day.

Table 1. Number of patients undergoing computed tomography (CT) examinations according to referring area and day for each model

Model 1 consisted of an administrative assistant and a radiographer; Model 2 consisted of a medical imaging assistant (MIA) and a radiographer; Model 3 consisted of two radiographers (usual practice); and Model 4 consisted of an MIA and two radiographers. ED, emergency department; ICU, intensive care unit

	Model 1 *n* (%)	Model 2 *n* (%)	Model 3 *n* (%)	Model 4 *n* (%)	Total *n* (%)[A]
No. ED patients	74 (46.3)	81 (50)	75 (47)	85 (49)	315 (48)
No. in-patients	60 (37.5)	64 (39)	63 (39)	75 (43)	262 (40)
No. out-patients	21 (13)	13 (8)	18 (11)	12 (7)	64 (10)
No. ICU patients	5 (3)	4 (2)	4 (3)	3 (2)	16 (2)
Total no. patients	160	162	160	175	657
Weekend	35 (22)	36 (22)	32 (20)	43 (25)	146 (22)
Weekday	125 (78)	126 (78)	128 (80)	132 (75)	511 (78)

[A]Percentages may not add to 100% due to rounding to the nearest whole number.

Table 2. Median time for patient flow through the computed tomography unit servicing the emergency department for each model

Model 1 consisted of an administrative assistant and a radiographer; Model 2 consisted of a medical imaging assistant (MIA) and a radiographer; Model 3 consisted of two radiographers (usual practice); and Model 4 consisted of an MIA and two radiographers. IQR, interquartile range; MIDLOS, medical imaging department length of stay

	Median (IQR) time (min)		
	From arrival to start	From arrival to finish (MIDLOS)	From start to finish
Model 1	20 (5–48)	35 (14–61)	8 (3–15)
Model 2	20 (9–46.5)	29 (16–51)	6 (3–10)
Model 3	25 (8–52)	40 (19–65)	10 (5–15)
Model 4	21 (8–41)	31 (16–48.5)	6 (3–11)

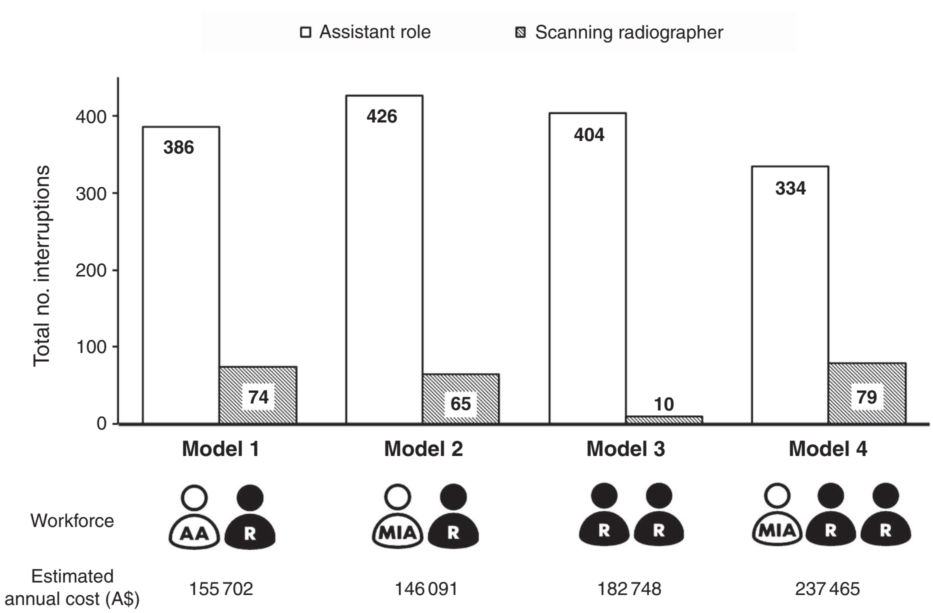

Fig. 2. Total number of interruptions, by model and role, showing the workforce mix and annual cost estimates for each model. AA, administrative assistant; MIA, medical imaging assistant; R, radiographer.

In each Model, the 'assistant' fielded a higher proportion of interruptions (Fig. 2). There was a significant difference in the proportion of interruptions during protocolling for assistants and radiographers between models ($\chi^2 = 9.20$, $P = 0.027$), but no significant difference in the proportion of interruptions during appointments for assistants and radiographers between models ($\chi^2 = 3.09$ $P = 0.38$). There was a significant difference in the proportion of 'issues' experienced for assistants and radiographers between models ($\chi^2 = 59.25$, $P < 0.001$).

Table 3. Frequency of interruptions in each model according to the position fielding the interruption, distributed across the type of interruption
Data show the number of interruptions, with percentages in parentheses. Model 1 consisted of an administrative assistant and a radiographer; Model 2 consisted of a medical imaging assistant (MIA) and a radiographer; Model 3 consisted of two radiographers (usual practice); and Model 4 consisted of an MIA and two radiographers. 'Issues' were defined as all other types of interruptions, mainly urgent face-to-face interactions with the referrer or radiologist to answer queries or to clarify, confirm, review or prioritise cases and patient care

	Telephone interruptions for protocol		Telephone interruptions for appointment		Interruptions for 'issues'	
	Assistant role *n* (%)	Radiographer *n* (%)	Assistant role *n* (%)	Radiographer *n* (%)	Assistant role *n* (%)	Radiographer *n* (%)
Model 1	11 (55)	9 (45)	269 (97)	8 (3)	106 (65)	57 (35)
Model 2	9 (52)	8 (48)	277 (97)	8 (3)	140 (74)	49 (26)
Model 3	15 (94)	1 (6)	269 (97)	8 (3)	120 (90)	1 (10)
Model 4	12 (50)	12 (50)	240 (95)	13 (5)	82 (60)	54 (40)

Cost estimates

Estimated annual labour costs of each workforce model showed that Model 2 (MIA + radiographer) had the lowest costs and Model 4 (MIA and two radiographers) had the highest (Fig. 2). In depth analysis of these costs was not performed, amounts are based on Queensland Health advertised rates for administrative staff (AO3 Level 4), operational staff (OO3 Level 4) and health practitioners (HP4 Level 2 + HP3 Level 4).[22] Annual labour cost estimates were calculated from advertised Queensland Health wage rates.

Discussion

This study presents a trial of four workforce models in the CTED for the primary outcomes of efficiency (measured MIDLOS) and patient throughput (number of scans performed). Secondary outcomes were workforce model cost and the frequency of interruptions. On comparing the three two-staff models (Models 1–3), this study demonstrated assistant models achieved similar efficiency (Table 2) and throughput (Table 1), suggesting effective workforce alternatives are available. Timing breakdowns of the different components of the scanning process suggested the MIA in Model 2 achieved the lowest MIDLOS of all two-staff models (Models 1–3) and may be the most efficient of all models, in the patient preparation component. Perhaps this reflects how certain roles performed by a motivated assistant could be similar or superior in quality to the same roles performed by an AHP.[1,4,7–9,15,23]

This study also offered an alternative model that could facilitate staff upskilling (Model 4), with the MIA undertaking the assistant role while one radiographer scans and the other is the trainer. Model 4 offered overall the best examination times and throughput, albeit less than first anticipated. One explanation could be role ambiguity between the assistant and the AHP (non-scanning radiographer), a known barrier to assistant workforce performance.[2,3,5,7,9,15,24,25]

The workforce model with the highest annual cost was Model 4 (MIA + two radiographers) and the one with the lowest annual cost was Model 2 (MIA + radiographer). Cost saving by delegation to an assistant workforce is gaining traction as providers look for more efficient ways of delivering health care.[1,3,4,7,18,23] Decision makers concerned with the higher cost of Model 4 can consider the potential benefits, including the opportunity for staff training for CTED succession planning, and the potential for greater compliance in efficiency targets. In addition, considerations of Model 2 should take into account the inherent differences in assistant abilities due to training and scope.[3,5,8,9,15,25]

When viewing the interruptions data as workload, it was interesting that at least half the interruptions were fielded by the assistant role across all models (Table 3). Studies have demonstrated that an assistant can perform many of the duties of an AHP,[1,5–7,9,10,15] with up to one quarter of AHP tasks able to be delegated to a trained assistant.[3,6,23] The findings of the present study certainly suggest that a proportion of the CT radiographer role can be delegated to a trained assistant.

Working within a CTED is challenging due to higher workloads and patient acuity, both known contributors to burnout and stress.[26] The present study demonstrated between 34 and 104 interruptions per day (0800–1700 hours) across all models, illustrating a potential vulnerability within the CTED. Although healthcare interruptions are essential to communication and efficiency,[27–31] they also contribute to delays, frustration, stress and medical errors.[14,27–30,32–34] The present study was consistent with others demonstrating that telephone calls were the major source of interruption.[29,31,33,34] Limiting interruptions to between consultations is impossible,[29,30] but appropriately trained assistants may be used to effectively triage interruptions, reducing the burden on the scanning radiographer.

Some argue that AHA roles should be used to collaboratively complement, rather than substitute, the AHP workforce.[5,8,15] In either case, engaging an AHA can deliver similar benefits to the patient, staff and organisation.[1,3,5,8] Acknowledging that MIAs cannot and should not completely replace radiographers, we suggest that, with appropriate workforce design, a more effective skills mix is available (e.g. using substitution as an interim measure during practice expansion where workloads exceed the capabilities of one radiographer, yet are insufficient for two radiographers). Furthermore, incorporating an assistant may allow CTED radiographers to focus on more specialised tasks, presenting possibilities for maximising and extending existing scopes of practice.[1,2,5–7,9,15,35,25]

This study presented a trial of four workforce models in the CTED, but there were inherent limitations in size and with being conducted at a single site. The results of this study reflect the observation period of 0800–1700 hours, so future studies could consider 24-h observations to account for night–day differences. Although the Hawthorne effect was possible,[36] it was likely consistent across all models. Duties within the CTED are diverse;

further investigation into the proportion of duties the CT assistant and nurse undertake is needed. Validated tools should be used to obtain specific staff, participant and patient experience and satisfaction data, further demonstrating the impacts of each workforce model. The frequency and impact of radiographer fatigue leave is an important area to investigate, particularly considering the safety implications. This study was unable to investigate all three-staff workforce models, such as supplementing an AA with Model 3. Further investigation is needed into the effect of each model on concurrent training programs, and the roles of all participants should be clarified to mitigate role ambiguity.

Conclusion

This study demonstrated that the MIA model (Model 2) was the most efficient of all two-staff models (Models 1–3) and offered the cheapest workforce, slightly higher throughput and faster patient flow. Not surprisingly, the additional staff model (Model 4; MIA + two radiographers) offered overall superior examination times and throughput, with fewer interruptions, although workforce cost and possible role ambiguity were limitations of this model. Furthermore, Model 4 may offer greater training opportunity for staff upskilling (succession planning) and reduced workforce stress and burnout. The findings of this study align with those of others reporting the viability of assistant workforces in clinical practice. Ultimately, the selection of workforce models will depend on organisational contextual factors. Our findings may inform organisations of important aspects of multiple workforce alternatives that may support organisational planning, workforce redesign and expansion.

Competing interests

The authors declare no conflicts or competing interest.

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