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The influence of computed tomography utilization on patient flow in emergency department

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The influence of computed tomography utilization on patient flow in emergency department

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All those designated as authors in this work met all four criteria for authorship including 1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work 2) Drafting the work or revising it critically for important intellectual content 3) Final approval of the version to be published and 4) Agreements 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.

Each author are able to identify which co-authors are responsible for specific other parts of the work. In addition, authors have confidence in the integrity of the contributions of their co-authors.

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Abstract

Objective: The utilization of computed tomography (CT) has grown rapidly. Considering the issue of emergency department (ED) overcrowding, it is important to evaluate whether the CT scan delays or facilitates patient disposition in the ED.

Methods: This retrospective, one-year, cohort study was conducted in five EDs and included all adult non-trauma patients. Patients were grouped by whether or not they underwent a CT scan (CT and non-CT groups, respectively). The ED lengths of stay (LOS) between patients with and without CT scans were compared by stratifying different dispositions and diagnoses.

Results: The CT scan prolonged patient ED LOS among those who were discharged from the ED. Among patients admitted to the observation unit and then discharged, the ED LOS was similar between the CT and non-CT groups. Except for patients diagnosed with cardiovascular disease, CT scans facilitated patient admission to the general ward. CT scans also facilitated admission to the intensive care unit for patients with nervous system disease, neoplasm, and digestive disease.

Conclusion: Although CT scans delayed patient discharge from the ED, CT shortened ED LOS among patients with particular diagnoses who were hospitalized after their ED visit.

Strengths and limitations of this study

1. This study was conducted across the largest healthcare system in Taiwan, which receives 8–10% of the national health insurance budget according to government statistics. The study sites were geographically well dispersed nationwide.
2. The very large sample size, with 293,426 ED visits, enabled assessment of multiple potential factors to estimate the influence of computed tomography utilization on patient flow in emergency department.
3. The study sites belonged to the same healthcare system, potentially limiting the implications of the conclusions.

Introduction

Computed tomography (CT) utilization has grown rapidly due to its recognized clinical value in nearly all areas of medicine, a trend enabled by technologic advances and widespread availability. The utilization of CT scanning in the acute setting nearly tripled from 1996 to 2010.[1] At the same time, the relatively high radiation doses associated with CT have also raised health concerns.[2-4] Multiple factors have contributed to the increase in CT use, such as physicians' uncertainty of patient diagnosis[5 6] patients' limited understanding of radiation exposure and risk.[7] Whether or not CT scans help dispose patients in the emergency department (ED) is still controversial. Some studies have stated that CT use might not affect patient outcomes.[8-11] However, other studies have suggested that CT scans may reduce the time to disease diagnosis, improve clinical outcome and help patient disposition. For instance, the proportion of ED visits with a diagnosis of pulmonary embolism has increased significantly, and this rise can be attributed in large part to the increased availability and use of CT.[12] Ng et al. reported that early abdominopelvic CT for acute abdominal pain may reduce mortality.[13] Systermans et al. suggested that abdominal CT scans frequently changed the clinical diagnosis and patient disposition.[14] Kocher et al. stated that the increased use of CT in the ED was associated with a decline in admissions or transfers.[15] Since ED overcrowding has become an international health issue,[16 17] it is important to evaluate whether use of CT delays or facilitates patient disposition in the ED. However, it is very hard to evaluate the influence of CT scan on the time consuming of patient disposition. Because, the clinical condition in patient with and without CT scans is different. Previous study has stated that the indirect effect of CT use may be increased length of stay (LOS) in the ED.[18] It is not fair to simplify this problem by comparing the average ED LOS of patients with and without CT scans. Therefore, the purpose of this study was to investigate the influence of CT utilization on ED patient flow with ED LOS as outcome variable by stratifying patient with different dispositions and diagnosis.

Methods

Study Design

This was a retrospective, one-year, cohort study approved by the Chang Gung Medical Foundation Institutional Review Board. Patient records and information were anonymized and de-identified prior to analysis.

Study Setting and Population

This study was conducted across the largest healthcare system in Taiwan, which receives 8–10% of the national health insurance budget according to government statistics. From 1 July 2011 to 30 June 2012, five EDs within this healthcare system were involved in the study. The five EDs were geographically well dispersed nationwide. Two EDs were tertiary referral medical centers with over 3500 and 2500 beds. The other three were secondary regional hospitals with over 1200, 1000, and 250 beds each. Other than the smallest ED, the other four EDs were the largest in their counties. The cumulative number of mean annual visits in the five EDs was over 480,000 per year. All adult non-trauma patients who presented to the EDs within the study period were included. Except for the hospital capacity, the five EDs had no difference in services provided, staffing, and equipment. The CT scan was available all day long in these five EDs. There were no differences in practice patterns or culture between the hospitals.

Study Protocol

To study the influence of CT utilization on patient flow, patients presenting to the ED who underwent at least one CT scan were defined as the CT group; the others were the non-CT group. The relationship between CT utilization and patient dispositions and ED LOS was analyzed to determine if CT use influenced patient flow.

Patient demographic factors, including age, sex, visit characteristics (triage category, time of arrival, final disposition, and ED LOS), hospital factors (hospital type and treating physician), and diagnosis were obtained from the ED administrative database and studied in reference to CT utilization. Diagnoses were grouped into categories using the diagnostic codes from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

Triage category was defined according to the Five Level Taiwan Triage and Acuity Scale, formulated by the Department of Health in Taiwan. According to these criteria, patients identified as triage levels 1 and 2 should be seen immediately or within 10 minutes, respectively, and are defined as urgent. Patients with triage levels 3, 4, and 5 should be assessed within 30 minutes, 60 minutes, or 120 minutes, respectively, and are classified as non-urgent.

Measures

Patient dispositions and ED LOS were documented as the primary outcomes. The ED

LOS was defined from the initial time that the patient presented to the emergency department as documented by the triage nurse to the final time that patient left ED. The dispositions were classified into the following five groups: discharge from ED, discharge from observation room, admission to general ward, admission to intensive care unit (ICU), and ED mortality. Patients transferred to other hospitals for admission were categorized as admitted; those discharged against medical advice or outpatient transference were categorized as discharged.

Data Analysis

Data were analyzed using the Student's t-test, $\chi 2$ test, and linear regression, as appropriate. A P value < 0.05 was regarded as statistically significant. SPSS version 12.0 (SPSS, Chicago, IL) was used for all statistical analyses.

Results

During the one-year study, 293,426 adult non-trauma patients visited the five EDs. Among them, 11.4% of patients received CT scans; 95.9% received one CT scan, 3.7% received two CT scans, and 0.4% received more than three CT scans. The patients' basic demographic factors (age, sex, and distribution in medical settings, time of arrivals, triage, treating physicians, and diagnostic categories) of the two study groups were compared in Table 1. Continues variable (age) was analyzed by Student's t-test, and all other category variables were analyzed by $\chi 2$ test. A P value < 0.05 was regarded as statistically significant. The CT scans were most used in diagnoses of nervous systemic disease (ICD-9-CM: 320–389 and 430–438), followed by neoplasms (ICD-9-CM: 140–239), digestive systemic disease (ICD-9-CM: 520–579), genitourinary systemic disease (ICD-9-CM: 580–629), cardiovascular systemic disease (ICD-9-CM: 390–429 and 439–459), and respiratory systemic disease (ICD-9-CM: 460–519). CT scans for these six disease categories accounted for 77.1% of total CT scans in the five EDs.

Table 1 Patients' basic demographic factors

	CT used		CT not used		P value
Age	60.5	±18.34	53.7	±19.67	<0.001
Sex					
Male	18101	12.3%	129005	87.7%	<0.001
Female	15235	10.4%	131085	89.6%	
Hospital					
Center	21523	12.7%	147499	87.3%	<0.001
Region	11813	9.5%	112591	90.5%	
Time of arrival					
Morning	15172	12.8%	103630	87.2%	<0.001
Evening	13146	11.4%	102392	88.6%	
Night	5018	8.5%	54068	91.5%	
Triage					
Urgency	10428	19.6%	42853	80.4%	<0.001
Non-urgency	22908	9.5%	217237	90.5%	
Physician					
Visit staff	21051	11.5%	162100	88.5%	0.003
Resident	12285	11.1%	97990	88.9%	
Diagnostic category					
Nervous	11724	31.7%	25208	68.3%	<0.001
Neoplasms	1714	14.0%	10501	86.0%	
Digestive	6671	9.8%	61229	90.2%	
Genitourinary	2213	7.9%	25795	92.1%	
Cardiovascular	1456	7.5%	17914	92.5%	
Respiratory	1911	4.1%	44782	95.9%	
Others	7647	9.3%	74661	90.7%	

[*]Continues variable (age) was analyzed by Student's t-test, and all other category variables were analyzed by χ2 test. A P value < 0.05 was regarded as statistically significant.

Figure 1 displays the distribution of dispositions and ED LOS in the CT and non-CT groups. While the hospitalization rate of patients in the non-CT group was 24.7% (including 22.7% in the general ward and 2.0% in the ICU), the rate of subsequent CT use was 54.7% (including 47.0% in the general ward and 7.7% in the ICU). The hospitalization rate among patients in the CT group was higher than that of the non-CT group. The overall ED LOS for patients in the CT group was longer than that for patients in the non-CT group (16.6 hours vs. 13.0 hours). However, after stratifying by disposition, patients who were discharged from the ED or observation room after CT scan tended to have longer ED LOS, while those admitted to the general ward or ICU had shorter LOS (Fig. 1).

Linear regression was used to analyze the impact of CT on ED LOS in different diagnostic groups, while adjusting for potential confounding factors, including, age, sex, medical setting, time of arrival, and triage category (Fig. 2). With regard to patient discharge from the ED, CT prolonged ED LOS in the six diagnostic groups. While patients diagnosed with neoplasm who had undergone CT scans spent 3.5 more hours in the ED than patients diagnosed with neoplasm who had not undergone CT scans, patients diagnosed with nervous system disease who had undergone CT scans only spent 0.8 more hours in the ED than patients diagnosed with nervous system disease who had not undergone CT scans.. In patients discharged from the observation room, only those diagnosed with digestive disease had prolonged ED LOS after CT scan. Among patients admitted to the general ward, CT use tended to shorten ED LOS, except among those who were diagnosed with cardiovascular disease. In patients who received CT scans and were then admitted to the ICU, those diagnosed with nervous system disease, neoplasm, and digestive disease had shorter ED LOS.

Discussion

This study found that the overall rate of CT use in the 5 EDs was 11.4% (12.7% in medical centers and 10.4% in regional hospitals). According to a previous study, approximately 1 in 7 patients with an ED visit underwent a CT scan in the United States by 2007.[15] While there is a trend of increased CT use in the ED, the rate of CT use in this study was somewhat lower than that reported in the United States. The study revealed the CT use was associated with patient's age, sex, time of arrival, clinical urgency, hospital setting, and treating physician. Furthermore, CT use was more prominent among elderly and male patients. Patients visiting the ED with urgent clinical presentation at triage had a greater chance of undergoing CT scans. The reason why patients who visited medical centers were more likely to receive CT scans might be related to clinical complexity. The rate of CT use during evening and night shifts was lower than that during the day shift. This might be because during off-hours of the outpatient department, patients visited the ED for relatively non-urgent problems; therefore, there was a lower proportion of CT use.

The CT scan plays an important role in the diagnosis and disposition of patients with acute and sometimes life-threatening illnesses. However, according to a previous study, the indirect effect of CT use may be increased LOS in the ED.[18] Overall, the mean ED LOS for patients who underwent CT scans was longer than that for patients who did not; however, it is not fair to simplify this problem by comparing the average ED LOS of patients with and without CT scans. According to this study, patient disposition was significantly different between the CT and non-CT groups. While most patients in the non-CT group were discharged from the ED, most patients in the CT group were hospitalized. This was because when patients received CT scans in the ED, it may be assumed that these patients had more urgent clinical presentations. To deal with the discrepancies in patient disposition demographics, this study compared ED LOS by stratifying patient dispositions and using linear regression to adjust for possible confounding factors. The results indicated that prolonged ED LOS mainly occurred among patients who were discharged from the ED. However, if patients were ever admitted to the observation room before discharge, the ED LOS between the CT and non-CT groups was similar. When CT scans were utilized, patients diagnosed with nervous system disease, neoplasm, digestive disease, genitourinary disease, and respiratory disease who were admitted to the general ward had shorter ED LOS, and those diagnosed with nervous disease, neoplasm, and digestive disease who were admitted to the ICU had shorter ED LOS. According to previous studies, CT scans facilitated the diagnostic process.[13,14] Systermans et al. reported that abdominal CT scans frequently changed the clinical diagnosis and patient disposition.[14] In addition, they also reported that the rate of pulmonary embolism diagnosis in the ED increased significantly along with the increased availability and use of CT.[12] Hoffmann et al. suggested early coronary CT angiography might significantly improve patient management in the ED.[19] According to the current study, using CT scan to confirm diagnosis may delay patient discharge by an average of 1.5 hours, but it could accelerate patient admission to the general ward and ICU by an average of 11.5 hours and 7 hours, respectively. Patients who were hospitalized after an ED visit had more complex clinical problems than those who were discharged from the ED. In addition, ED overcrowding is a worldwide problem; thus, it is important to facilitate patient disposition by speeding up the diagnostic process. Conversely, CT use delayed patient discharge from the ED, but without CT to rule out life-threatening problems, more patients might be hospitalized for observation.[15] This further exhausts the limited hospital capacity and exacerbates the issue of ED overcrowding. Furthermore, it is well documented in the literature that between many imaging studies obtained in the emergency department are obtained for medical legal reasons and do not substantively add to the patients diagnosis or care. To improve the diagnostic process, adherence to establish guidelines and best practices would eliminate unnecessary imaging, which would also increase the speed of diagnosis and ED disposition.

Although CT scans may aid in patient diagnosis, CT scans may sometimes be used to allay physicians' fears of misdiagnosis.[5 6] A previous study reported that most patients presenting to the ED with syncope or dizziness but without focal neurologic deficits may not benefit from head CT.[11] Another study suggested that there was no need for CT scans in most patients with suspected kidney stones, as there was no significant differences in the risk of subsequent serious adverse events, pain scores, return to the ED, or hospitalizations. In addition, young people are more sensitive to radiation exposure, and a previous study demonstrated that excess radiation-related relative risks of carcinogenesis decrease with increasing age at exposure up until the age of 30 years.[20 21] Pearce et al. noted a positive association between radiation dose from CT scans and the incidence of leukemia and brain tumors.[2] Therefore, although CT scans facilitate patient flow in the ED, it is still important to use clinical discretion to avoid unnecessary exposure to radiation.

Limitations

This study has several limitations. First, the five study sites belonged to the same healthcare system, potentially limiting the implications of the conclusions. For example, ED overcrowding was severe in the study location, which also influenced ED LOS and fees for hospitalization; these factors may have altered the decision to admit patients. Second, patients were grouped by ICD-9-CM and not according to the chief complaint. On the other hand, the CT type, including the scan position and use of contrast, was unknown, so it was not possible to evaluate the reasons for CT use in any individual patient. Third, due to the limitations of the retrospective design, there might be some confounding factors not measured in this analysis that could influence patient hospitalization or ED LOS. Further prospective studies are needed to determine the relationship between CT use and patient flow.

Conclusion

According to this study, CT scans seemed not delayed patient disposition in ED. While CT scans facilitated patient disposition if they were finally hospitalized, CT scans mildly prolonged ED LOS in patient discharge from the ED. However, to improve the diagnostic process and use CT more efficiently, adherence to establish guidelines and best practices would eliminate unnecessary imaging, which would increase the speed of diagnosis and ED disposition.

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Conflicts of interest statement : none to declare

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Figure legend

Figure 1 The distribution of dispositions and Emergency department length of stay (ED LOS) in the CT and non-CT groups. The unit of ED LOS is hour.

Figure 2 The influence of CT scan on Emergency department length of stay (hours) in different diagnostic groups, while adjusting for potential confounding factors, including, age, sex, medical setting, time of arrival, and disease acuity by linear regression.

Data sharing statement: No additional data available

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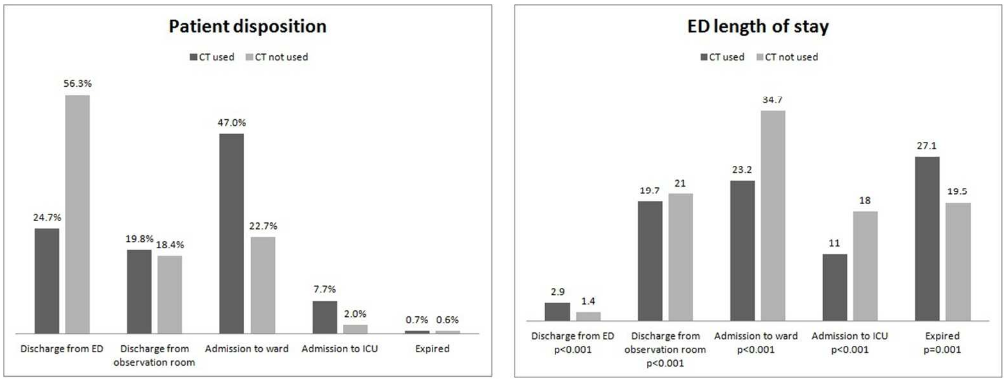

Figure 1
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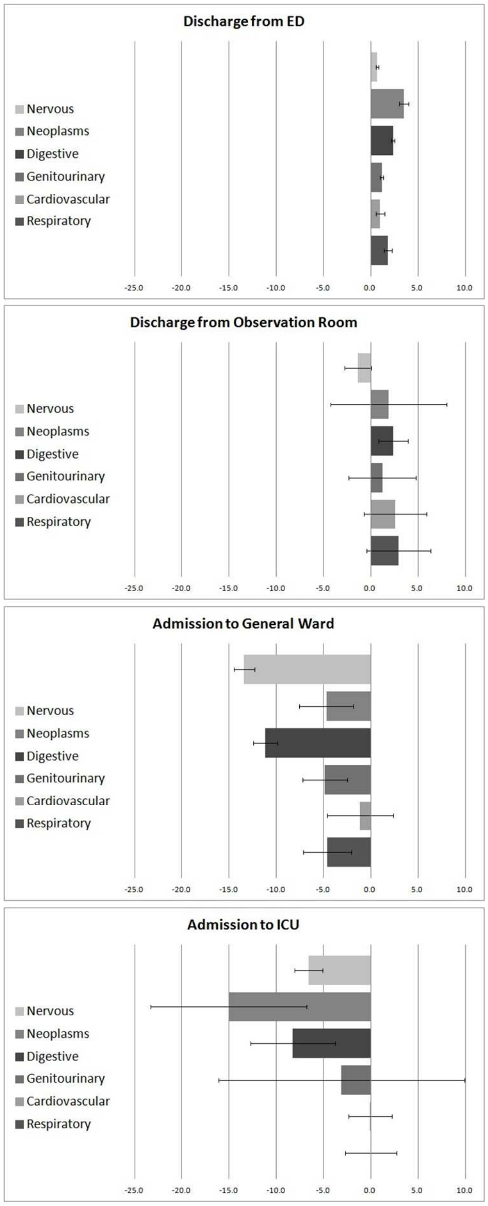

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STROBE Statement

Checklist of items that should be included in reports of observational studies

Section/Topic	Item No	Recommendation	Reported on Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Section/Topic	Item No	Recommendation	Reported on Page No
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	10
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12
		(*b*) Report category boundaries when continuous variables were categorized	12
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	12
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12
Discussion			
Key results	18	Summarise key results with reference to study objectives	18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

**Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.*

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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The influence of computed tomography utilization on patient flow in the emergency department: a retrospective one year cohort study

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All those designated as authors in this work met all four criteria for authorship including 1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work 2) Drafting the work or revising it critically for important intellectual content 3) Final approval of the version to be published and 4) Agreements 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.

Each author are able to identify which co-authors are responsible for specific other parts of the work. In addition, authors have confidence in the integrity of the contributions of their co-authors.

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Abstract

Objective: The utilization of computed tomography (CT) has grown rapidly. Considering the issue of emergency department (ED) overcrowding, it is important to evaluate whether the CT scan delays or facilitates patient disposition in the ED.

Methods: This retrospective one year cohort study was conducted in five EDs and included all adult non-trauma patients. Patients were grouped by whether or not they underwent a CT scan (CT and non-CT groups, respectively). The ED length of stay (LOS) and hospital LOS between patients with and without CT scans were compared by stratifying different dispositions and diagnoses.

Results: The CT scan prolonged patient ED LOS among those who were directly discharged from the ED. Among patients admitted to the observation unit and then discharged, patients diagnosed with nervous system disease had shorter ED LOS if they received CT scan. CT scans facilitated patient admission to the general ward. CT scans also accelerated patients admission to the intensive care unit (ICU) for patients with nervous system disease, neoplasm, and digestive disease. Finally, patients admitted to the general wards had shorter hospital LOS if they received CT scans in the ED.

Conclusion: Although CT scans delayed patient discharge from the ED, CT shortened ED LOS among patients with particular diagnoses who were hospitalized after their

ED visits.

Strengths and limitations of this study

1. This study was conducted across the largest healthcare system in Taiwan, which receives 8–10% of the national health insurance budget according to government statistics. The study sites were geographically well dispersed nationwide.
2. The very large sample size, with 293,426 ED visits, enabled assessment of multiple potential factors to estimate the influence of computed tomography utilization on patient flow in emergency department.
3. The study sites belonged to the same healthcare system, potentially limiting the implications of the conclusions.

Introduction

Computed tomography (CT) utilization has grown rapidly due to its recognized clinical value in nearly all areas of medicine, a trend enabled by technologic advances and widespread availability. The utilization of CT scanning in the acute setting nearly tripled from 1996 to 2010.[1] At the same time, the relatively high radiation doses associated with CT have also raised health concerns.[2-4] Multiple factors have contributed to the increase in CT use, such as increased availability and speed of obtaining CT, or possible patient expectations. Whether or not CT scans help disposition of patients in the emergency department (ED) is still controversial. Some studies have stated that CT use might not affect patient outcomes.[5-8] However, other studies have suggested that CT scans may reduce the time to disease diagnosis, improve clinical outcome and help patient disposition. For instance, the proportion of ED visits with a diagnosis of pulmonary embolism has increased significantly, and this rise can be attributed in large part to the increased availability and use of CT.[9] Ng et al. reported that early abdominopelvic CT for acute abdominal pain may reduce mortality.[10] Systermans et al. suggested that abdominal CT scans frequently changed the clinical diagnosis and patient disposition.[11] Kocher et al. stated that the increased use of CT in the ED was associated with a decline in admissions or transfers.[12] Since ED overcrowding has become an international health issue,[13 14] it is important to evaluate whether use of CT delays or facilitates patient disposition in the ED. However, it is very hard to evaluate the influence of CT scan on patient throughput because of the myriad of variables that affect patient disposition. Previous study has stated that the indirect effect of CT use may be increased length of LOS in the ED.[15] It is over-simplistic to compare the average ED LOS of patients with and without CT scans. Therefore, the purpose of this study was to investigate the influence of CT utilization on ED patients flow with ED LOS as outcome variable by stratifying patients with different dispositions and diagnoses.

Methods

Study Design

This retrospective one year cohort study was approved by the Chang Gung Medical Foundation Institutional Review Board. Patient records and information were anonymized and de-identified prior to analysis.

Study Setting and Population

This study was conducted across the largest healthcare system in Taiwan, which receives 8–10% of the national health insurance budget according to government statistics. From 1 July 2011 to 30 June 2012, five EDs within this healthcare system were involved in the study. The five EDs were geographically well dispersed nationwide. Two EDs were tertiary referral medical centers with over 3500 and 2500 beds. The other three were secondary regional hospitals with over 1200, 1000, and 250 beds each. Other than the smallest ED, the other four EDs were the largest in their counties. The cumulative number of mean annual visits in the five EDs was over 480,000 per year. All adult non-trauma patients who presented to the EDs within the study period were included. Except for the hospital capacity, the five EDs had no difference in services provided, staffing, and equipment. The CT scan was available 24 hours every day in these five EDs.

Study Protocol

All ED patients in the five hospitals were divided into computerized axial tomography (CT) group (patients receiving at least one CT scan during ED stay) and non-CT group (patients without any CT scan during ED stay). Patient demographic factors, including age, sex, visit characteristics (triage category, time of arrival, disposition, ED LOS, and hospital LOS), hospital factors (hospital type and treating physician), and diagnoses were obtained from the ED administrative database and studied in reference to CT utilization. Time of arrival were divided into morning shift (8:00~16:00), evening shift (16:00~00:00), and night shift (00:00~8:00). The dispositions included discharge, admission to observation room then discharge, admission to general ward, admission to ICU, and ED mortality. There were observation rooms in the five EDs of this study. Two kinds of patient were admitted to observation units. First, patient had no definite diagnosis and admitted to observation unit to watch out clinical change. Second, patient who stood by hospital admission in the EDs were also admitted to observation units. So, there were some patients in the observation rooms discharged, and others were admitted to the hospital. Patients transferred to other hospitals for admission were categorized as admitted; those discharged against medical advice or outpatient transference were categorized as discharged. Triage category was defined according to the Five Level Taiwan Triage and Acuity Scale, formulated by the Department of Health in Taiwan. According to these criteria, patients identified as triage levels 1 and 2 should be seen immediately or within 10 minutes, respectively, and are defined as urgent. Patients with triage levels 3, 4, and 5 should be assessed within 30 minutes, 60 minutes, or 120 minutes, respectively, and are classified as non-urgent.[16] Diagnoses were grouped into categories using the diagnostic codes from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

Measures

Patient dispositions and ED LOS were documented as the primary outcomes. The ED LOS was defined from the initial time that the patient presented to the emergency department as documented by the triage nurse to the final time that patient left the ED. ED LOS were calculated in the following five points: discharge from ED, discharge from observation room, admission to general ward, admission to ICU, and ED mortality. The hospital LOS of patient who were admitted to general ward or ICU were documented as secondary outcome to evaluate the prognosis of patient.

Data Analysis

The patient's age, ED LOS and hospital LOS were reported as means with standard deviations (SDs), and analyzed by Student's t test. The distribution of category demographic factors including patient's sex, visit characteristics (triage category, time of arrival), hospital factors (hospital type and treating physician), and diagnoses was presented with number and percentages. Chi-square tests were used to evaluate the association between these parameters and CT scan.

To analyze the influence of CT scan on ED LOS and hospital LOS with adjusting for potential confounding factors including patient's age sex, visit characteristics (triage category, time of arrival), hospital factors (hospital type and treating physician), multiple variable linear regression was applied.

To further reduce the heterogeneity between the study and control group. Propensity score (PS) matching was also used to control for potential confounding factors. The advantage of the PS matching method is the 2-step analysis design, which enables a balance of possible confounding factors between the treated and control groups before "seeing" the results in the 1st step of the analysis. The PS of a patient's probability of receiving CT scan was calculated according to multiple individual characteristics, including patient's age sex, visit characteristics (triage category, time of arrival), hospital factors (hospital type and treating physician) stratified with different diagnosis category via a logistic regression model in the 1st step of the analysis. Different PS matching methods were considered, including exact, sub-classification, nearest neighbor, optimal, and generic matching.[17 18] Nearest neighbor matching without replacement with a ratio of 1: 4 for all diagnosis categories except nervous system disease (1:1) was chosen based on the percent balance improvement, defined as improvement of the mean difference between groups before and after matching. Then, the ED LOS and hospital LOS were compared again between the matching groups with linear regression.

All analyses were 2-tailed and P-values <0.05 were considered statistically significant. SPSS version 12.0 (SPSS, Chicago, IL) and R (version 3.0.2; R Foundation for Statistical Computing, Vienna, Austria) were used for all statistical analyses.

Results

During the one-year study, 293,426 adult non-trauma patients visited the five EDs. Among them, 11.4% of patients received CT scans. Of these patients ongoing CT scan during ED stay, 95.9% received one CT scan, 3.7% received two CT scans, and 0.4% received three or more CT scans. Patient demographic factors, including age, sex, visit characteristics (triage category, time of arrival), hospital factors (hospital type and treating physician), diagnoses, dispositions, ED LOS, and hospital LOS of the two study groups are compared in Table 1. The continuous variables (age, ED LOS, hospital LOS) were analyzed by Student's t-test, and all other category variables were analyzed by $\chi 2$ test. A P value < 0.05 was regarded as statistically significant. The CT scans were most used in diagnoses of nervous system disease (ICD-9-CM: 320–389 and 430–438), followed by gastrointestinal disease (ICD-9-CM: 520–579), genitourinary disease (ICD-9-CM: 580–629), pulmonary disease (ICD-9-CM: 460–519), neoplasms (ICD-9-CM: 140–239), and cardiovascular disease (ICD-9-CM: 390–429 and 439–459). CT scans for these six disease categories accounted for 77.1% of total CT scans in the five EDs.

1 **Table 1** Patients' basic demographic factors

	CT used (33,336)		CT not used (260,090)		P value
Age	60.5	±18.34	53.7	±19.67	<0.001
Sex					
Male	18101	54.3%	129005	49.6%	<0.001
Female	15235	45.7%	131085	50.4%	
Triage					
Urgent	10428	31.3%	42853	16.5%	<0.001
Non-urgent	22908	68.7%	217237	83.5%	
Time of arrival					
8:00~16:00	15172	45.5%	103630	39.8%	<0.001
16:00~00:00	13146	39.4%	102392	39.4%	
00:00~8:00	5018	15.1%	54068	20.8%	
Physician					
Visit staff	21051	63.1%	162100	62.3%	0.003
Resident	12285	36.9%	97990	37.7%	
Hospital					
Center	21523	64.6%	147499	56.7%	<0.001
Region	11813	35.4%	112591	43.3%	
Disposition					
Discharge from ED	8246	24.7%	146539	56.30%	<0.001
Discharge from observation room	6607	19.8%	47831	18.40%	
Admission to general ward	15682	47.0%	58988	22.70%	
Admission to ICU	2557	7.7%	5175	2.00%	
ED mortality	244	0.7%	1557	0.60%	
Diagnostic category					
Nervous	11724	35.2%	25208	9.7%	<0.001
Gastrointestinal	6671	20.0%	61229	23.5%	
Genitourinary	2213	6.6%	25795	9.9%	
Pulmonary	1911	5.7%	44782	17.2%	
Neoplasms	1714	5.1%	10501	4.0%	
Cardiovascular	1456	4.4%	17914	6.9%	
Others	7647	22.9%	74661	28.7%	
ED LOS (hr)	16.6	±27.13	13.0	±27.28	<0.001
Hospital LOS (day)	12.7	14.44	12.5	12.99	<0.001

2 *Continues variable (age, ED LOS, and hospital LOS) was analyzed by Student's

t-test, and all other category variables were analyzed by χ2 test. A P value < 0.05 was regarded as statistically significant.

In non-CT group, there were 24.7% patients hospitalized after ED visits (including 22.7% admitted to the general ward and 2.0% to the ICU). In CT-group, there were 54.7% hospitalized after ED visits (including 47.0% admitted to the general ward and 7.7% to the ICU). The hospitalization rate among patients in the CT group was higher than that of the non-CT group. The overall ED LOS for patients in the CT group was longer than that for patients in the non-CT group (16.6 hours vs. 13.0 hours). However, after stratifying by disposition, patients who discharged from the ED with CT scan tended to have longer ED LOS, while those discharge from the observation room, or admitted to the general ward or ICU had shorter LOS (Fig. 1-A). The hospital LOS for patients admitted to general ward in the CT group was shorter than that for patients in the non-CT group, but the hospital LOS for patients admitted to ICU in the CT group was longer than that for patients in the non-CT group. (Fig. 1-B)

Linear regression was used to analyze the impact of CT on ED LOS and hospital LOS in different diagnostic groups, with adjusting for potential confounding factors, including patient's age sex, visit characteristics (triage category, time of arrival), hospital factors (hospital type and treating physician) in multiple variable regression model (Fig. 2-A, 2-B) and PS matching regression model (Fig. 3-A. 3-B). With regard to patients discharge from the ED, CT prolonged ED LOS in the six diagnostic groups. In patient discharged from the ED, patients had undergone CT scans spent more time in the ED than patients who had not undergone CT scans in all six diagnosis categories in both multiple variable regression model and PS matching regression model. In patients discharged from the observation room, those diagnosed with nervous system disease had shorten ED LOS in both models, but those diagnosed with gastrointestinal disease, pulmonary disease, and cardiovascular disease had prolonged ED LOS after CT scan in the multiple variable regression model but not in the PS matching regression model. Among patients admitted to the general ward, CT use tended to shorten ED LOS, except among those who were diagnosed with cardiovascular disease in multiple variable regression model, but in PS matching regression model, CT use tended to shorten ED LOS in all six diagnose categories. In patients who received CT scans and were then admitted to the ICU, those diagnosed with nervous system disease, neoplasm, and gastrointestinal disease had shorter ED LOS in both models. With regard to hospital LOS in patients admitted to general ward, CT scan tended to shorten hospital LOS in patients diagnosed with nervous system disease, gastrointestinal disease, and genitourinary disease in both models. CT scan did not influence hospital LOS in patient admitted to ICU.

Discussion

This study found that the overall rate of CT use in the 5 EDs was 11.4% (12.7% in medical centers and 10.4% in regional hospitals). According to a previous study, approximately 1 in 7 patients with an ED visit underwent a CT scan in the United States by 2007.[12] While there is a trend of increased CT use in the ED, the rate of CT use in this study was somewhat lower than that reported in the United States. The study revealed the CT use was associated with patient's age, sex, time of arrival, clinical urgency, hospital setting, and treating physician. Furthermore, CT use was more prominent among elderly and male patients. Patients visiting the ED with urgent clinical presentation at triage had a greater chance of undergoing CT scans. The reason why patients who visited medical centers were more likely to receive CT scans might be related to clinical complexity. The rate of CT use during evening and night shifts was lower than that during the day shift. This might be because during off-hours of the outpatient clinics, patients visited the ED for relatively non-urgent problems; therefore, there was a lower proportion of CT use.

The CT scan plays an important role in the diagnosis and disposition of patients with acute and sometimes life-threatening illnesses. However, according to a previous study, the indirect effect of CT use may be increased LOS in the ED.[15] Overall, the mean ED LOS for patients who underwent CT scans was longer than that for patients who did not; however, it is over-simplistic to compare the average ED LOS of patients with and without CT scans. According to the study, using CT scan to confirm diagnosis may delay patient discharge by an average of 1.5 hours, but it could accelerate patient admission to the general ward and ICU by an average of 11.5 hours and 7 hours, respectively and it also decreased 1 day of hospital stay in general wards after hospital admission. In the other words, prolonged LOS mainly occurred among patients who were directly discharged from the ED. However, if patients were ever admitted to the observation room before discharge, CT scan shortened the ED LOS in patients with nervous system disease, and in the other five diagnosis categories, there might be no significant difference. When CT scans were utilized, patients diagnosed with nervous system disease, neoplasm, gastrointestinal disease, genitourinary disease, pulmonary disease, and cardiovascular disease who were admitted to the general ward had shorter ED LOS, and those diagnosed with nervous disease, neoplasm, and digestive disease who were admitted to the ICU had shorter ED LOS. In addition to the ED LOS, CT scan in the ED also shortened the total hospital LOS in nervous system disease, gastrointestinal disease, and genitourinary disease after admission to general wards.

The reason why CT scan facilitated patient disposition might be that it shortened the diagnostic process.[13,14] Systermans et al. reported that abdominal CT scans frequently changed the clinical diagnosis and patient disposition.[11] In addition, they also reported that the rate of pulmonary embolism diagnosis in the ED increased significantly along with the increased availability and use of CT.[9] Hoffmann et al. suggested early coronary CT angiography might significantly improve patient management in the ED.[19] According to the study, the acceleration of diagnostic process was more predominant in patients diagnosed with nervous disease. Unlike other diagnostic groups, CT scan not only accelerated these patients admitting to general ward, it also shortened the LOS of these patients to discharge from observation room. According to our clinical experience, some patients presented ED with non-specified neurologic symptoms such as dizziness, vertigo, or headache, and observed in the observation room to wait symptom relived. With CT scan to rule out life threatening condition, physician might be more confident to let patient discharge and it shorten the LOS. Since ED overcrowding is a worldwide problem; thus, it is important to facilitate patient disposition by speeding up the diagnostic process. Conversely, CT use delayed patient discharge from the ED, but without CT to rule out life-threatening problems, more patients might be hospitalized for observation.[12] This further exhausts the limited hospital capacity and exacerbates the issue of ED overcrowding. Furthermore, it is well documented in the literature that between many imaging studies obtained in the emergency department are obtained for medical legal reasons and do not substantively add to the patients diagnosis or care. To improve the diagnostic process, adherence to establish guidelines and best practices would eliminate unnecessary imaging, which would also increase the speed of diagnosis and ED disposition.

Limitations

This study has several limitations. First, the five study sites belonged to the same healthcare system, potentially limiting the implications of the conclusions. For example, the LOS in these ED's is much longer when compared with other ED's around the world and certainly within the US and Western Europe. These differences may be explained by different definitions of observation and differences in the health care economics, patient expectations, or provider practice patterns. This may limit the generalizability of the current study. Second, patients were grouped by ICD-9-CM and not according to the chief complaint. On the other hand, the CT type, including the scan position and use of contrast, was unknown, so it was not possible to evaluate the reasons for CT use in any individual patient. Third, due to the limitations of the retrospective design, there might be some confounding factors not measured in this analysis that could influence patient hospitalization or ED LOS. Further prospective studies are needed to determine the relationship between CT use and patient flow.

Conclusion

According to this study, CT scans seemed not to have delayed patient disposition in ED. While CT scans facilitated patient disposition if they were finally hospitalized, CT scans mildly prolonged ED LOS in patient discharge from the ED.

Figure legend

Figure 1 (A) the emergency department length of stay (hour) and (B) hospital length of stay (day) of different dispositions in the CT and non-CT groups.

Figure 2 The influence of CT scan on (A) emergency department length of stay (hours) and (B) hospital length of stay (day) in different diagnostic groups, adjusting for potential confounding factors, including patient's age, sex, visit characteristics (triage category, time of arrival), and hospital factors (hospital type and treating physician) by multivariable linear regression.

Figure 3 The influence of CT scan on (A) emergency department length of stay (hour) and (B) hospital length of stay (day) in different diagnostic groups, adjusting for potential confounding factors, including patient's age, sex, visit characteristics (triage category, time of arrival), and hospital factors (hospital type and treating physician) by propensity matching linear regression.

Data sharing statement: No additional data available

Reference

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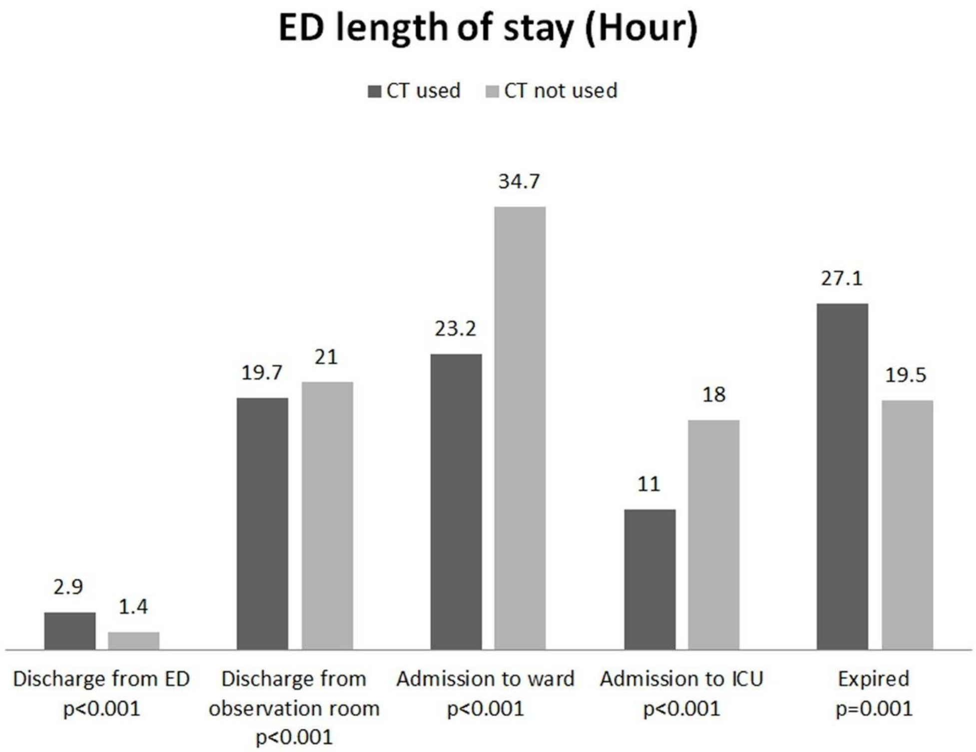

Figure 1-A
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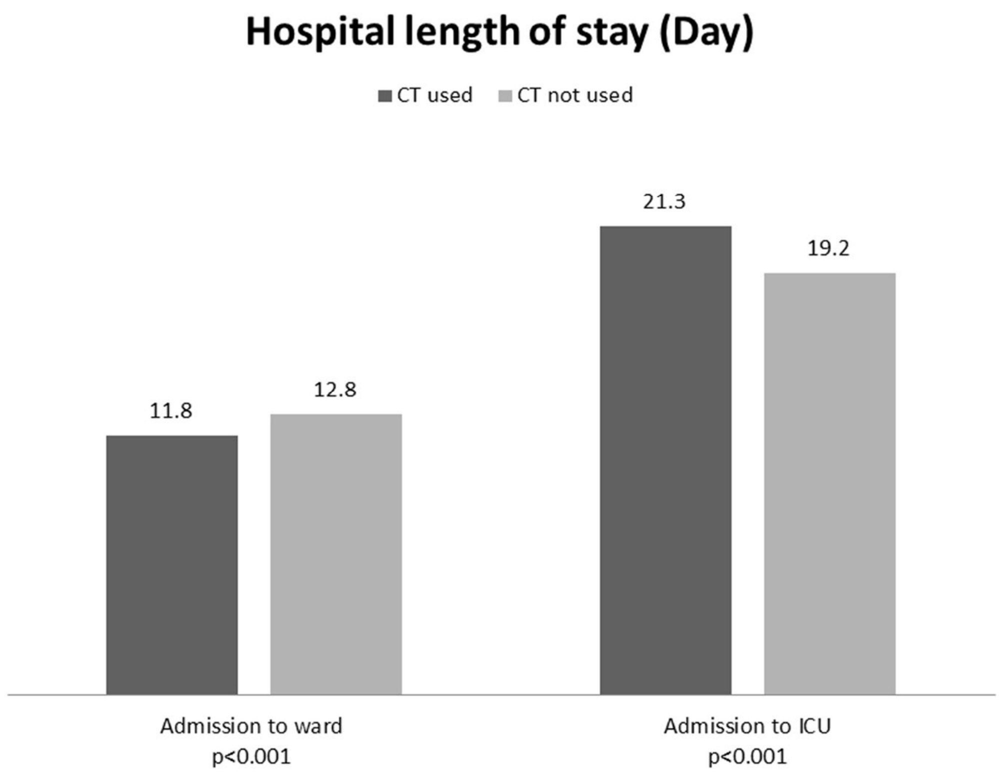

Figure 1-B
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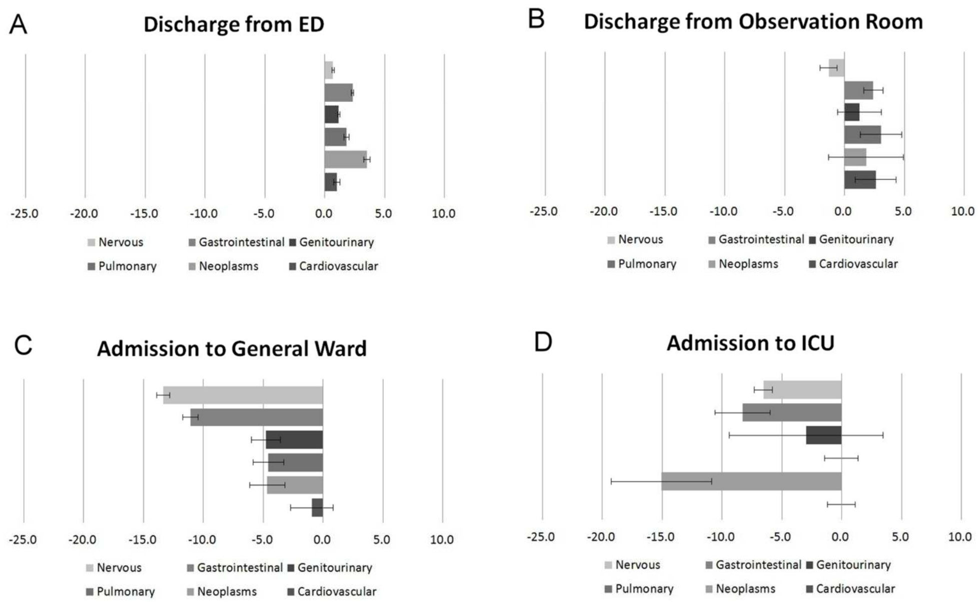

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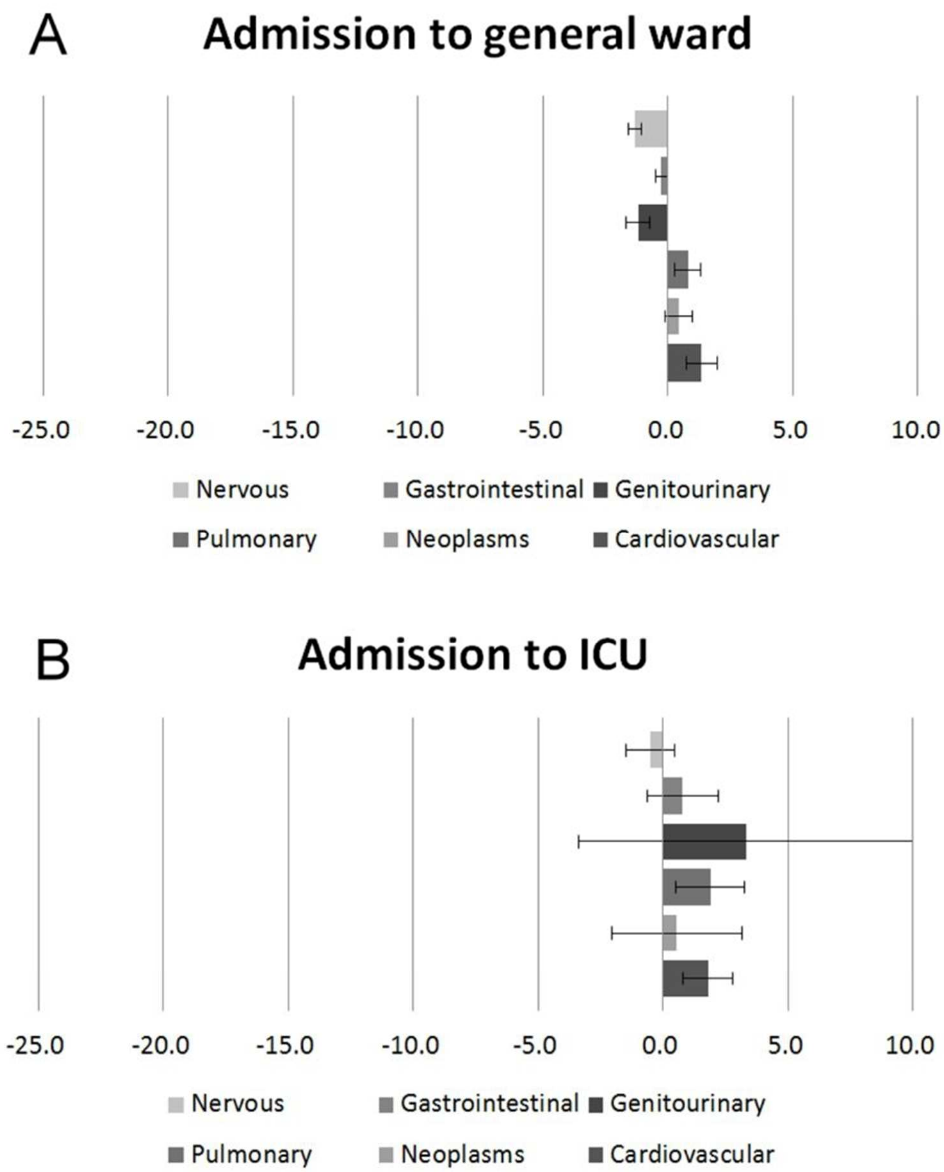

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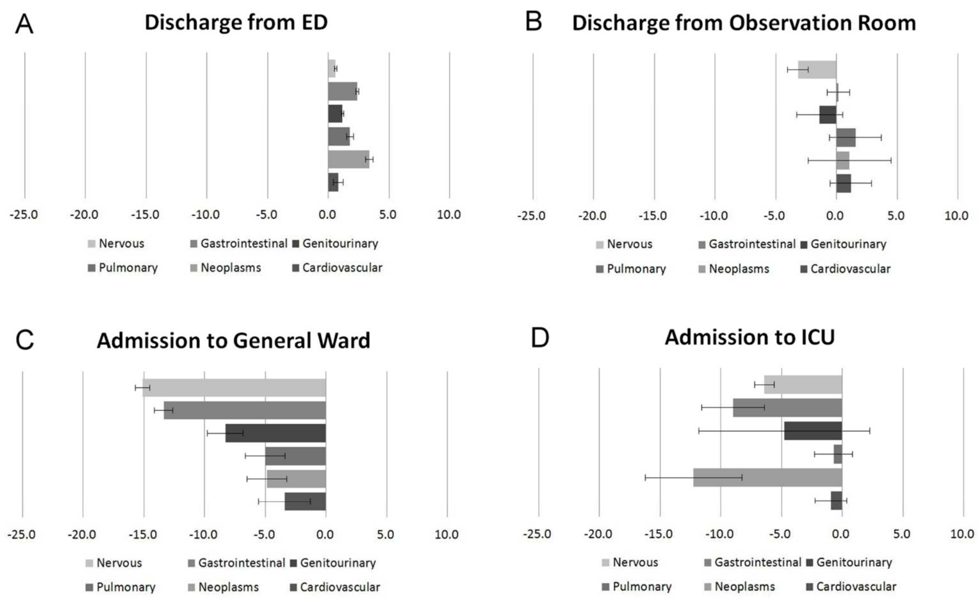

Figure 3-A
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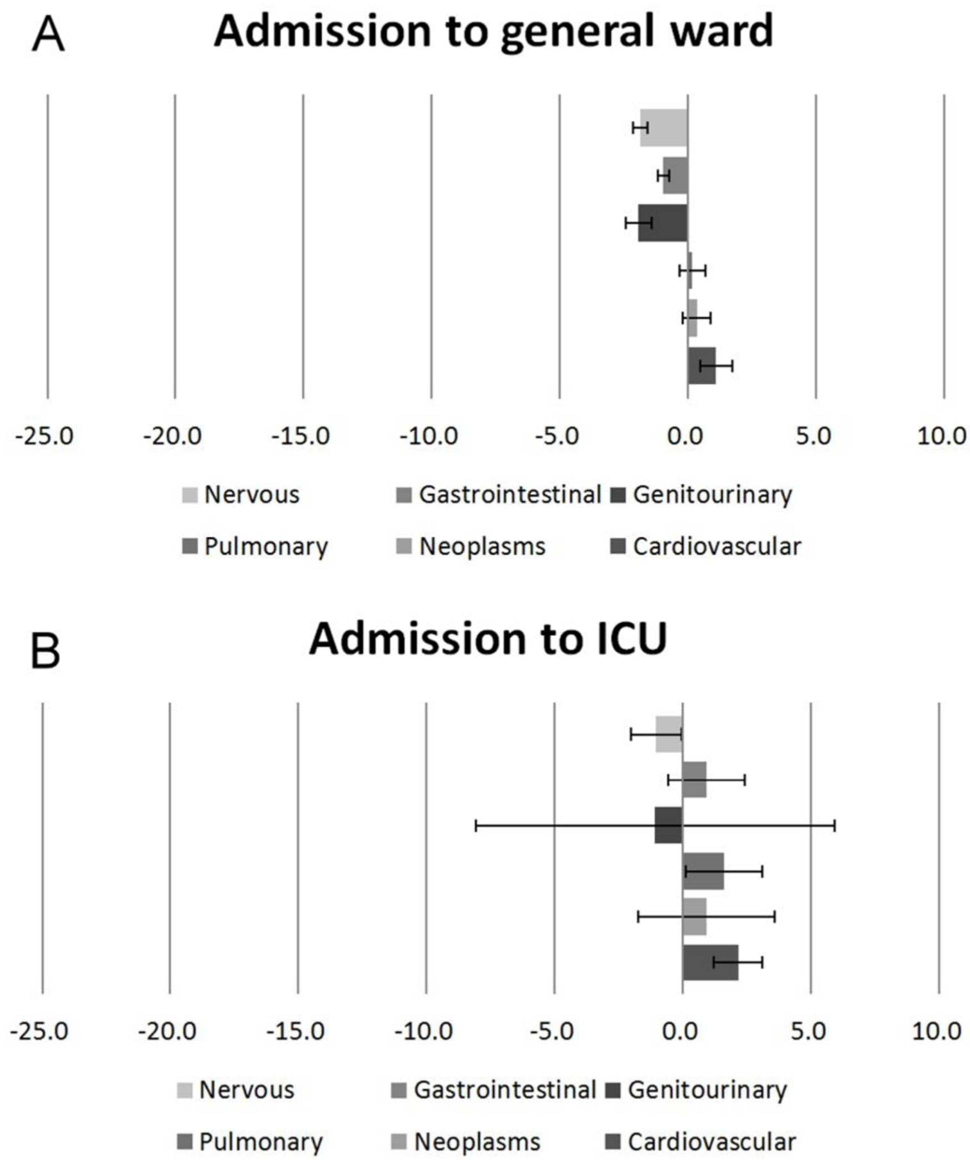

Figure 3-B
75x90mm (300 x 300 DPI)

STROBE Statement

Checklist of items that should be included in reports of observational studies

Section/Topic	Item No	Recommendation	Reported on Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	8
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	10
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Section/Topic	Item No	Recommendation	Reported on Page No
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	13
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	13
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	15
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	15
		(*b*) Report category boundaries when continuous variables were categorized	15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	15
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	15
Discussion			
Key results	18	Summarise key results with reference to study objectives	17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	21
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	23

**Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.*

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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The influence of computed tomography utilization on patient flow in the emergency department, a retrospective one year cohort study

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& Kuan-Fu Chen and Chien-Hung Lee contributed equally to this work.

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Each author are able to identify which co-authors are responsible for specific other parts of the work. In addition, authors have confidence in the integrity of the contributions of their co-authors.

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Abstract

Objective: The utilization of computed tomography (CT) has grown rapidly. Considering the issue of emergency department (ED) overcrowding, it is important to evaluate whether the CT scan delays or facilitates patient disposition in the ED.

Methods: This retrospective one year cohort study was conducted in five EDs and included all adult non-trauma patients. Patients were grouped by whether or not they underwent a CT scan (CT and non-CT groups, respectively). The ED length of stay (LOS) and hospital LOS between patients with and without CT scans were compared by stratifying different dispositions and diagnoses.

Results: The CT scan prolonged patient ED LOS among those who were directly discharged from the ED. Among patients admitted to the observation unit and then discharged, patients diagnosed with nervous system disease had shorter ED LOS if they received CT scan. CT scans facilitated patient admission to the general ward. CT scans also accelerated patients admission to the intensive care unit (ICU) for patients with nervous system disease, neoplasm, and digestive disease. Finally, patients admitted to the general wards had shorter hospital LOS if they received CT scans in the ED.

Conclusion: Although CT scans delayed patient discharge from the ED, CT shortened ED LOS among patients with particular diagnoses who were hospitalized after their

ED visits.

Strengths and limitations of this study

1. This study was conducted across the largest healthcare system in Taiwan, which receives 8–10% of the national health insurance budget according to government statistics. The study sites were geographically well dispersed nationwide.
2. The very large sample size, with 293,426 ED visits, enabled assessment of multiple potential factors to estimate the influence of computed tomography utilization on patient flow in emergency department.
3. The study sites belonged to the same healthcare system, potentially limiting the implications of the conclusions.

Introduction

Computed tomography (CT) utilization has grown rapidly due to its recognized clinical value in nearly all areas of medicine, a trend enabled by technologic advances and widespread availability. The utilization of CT scanning in the acute setting nearly tripled from 1996 to 2010.[1] At the same time, the relatively high radiation doses associated with CT have also raised health concerns.[2-4] Multiple factors have contributed to the increase in CT use, such as increased availability and speed of obtaining CT, or possible patient expectations. Whether or not CT scans help disposition of patients in the emergency department (ED) is still controversial. Some studies have stated that CT use might not affect patient outcomes.[5-8] However, other studies have suggested that CT scans may reduce the time to disease diagnosis, improve clinical outcome and help patient disposition. For instance, the proportion of ED visits with a diagnosis of pulmonary embolism has increased significantly, and this rise can be attributed in large part to the increased availability and use of CT.[9] Ng et al. reported that early abdominopelvic CT for acute abdominal pain may reduce mortality.[10] Systermans et al. suggested that abdominal CT scans frequently changed the clinical diagnosis and patient disposition.[11] Kocher et al. stated that the increased use of CT in the ED was associated with a decline in admissions or transfers.[12] Since ED overcrowding has become an international health issue,[13 14] it is important to evaluate whether use of CT delays or facilitates patient disposition in the ED. However, it is very hard to evaluate the influence of CT scan on patient throughput because of the myriad of variables that affect patient disposition. Previous study has stated that the indirect effect of CT use may be increased length of LOS in the ED.[15] It is over-simplistic to compare the average ED LOS of patients with and without CT scans. Therefore, the purpose of this study was to investigate the influence of CT utilization on ED patients flow with ED LOS as outcome variable by stratifying patients with different dispositions and diagnoses.

Methods

Study Design

This retrospective one year cohort study was approved by the Chang Gung Medical Foundation Institutional Review Board. Patient records and information were anonymized and de-identified prior to analysis.

Study Setting and Population

This study was conducted across the largest healthcare system in Taiwan, which receives 8–10% of the national health insurance budget according to government statistics. From 1 July 2011 to 30 June 2012, five EDs within this healthcare system were involved in the study. The five EDs were geographically well dispersed nationwide. Two EDs were tertiary referral medical centers with over 3500 and 2500 beds. The other three were secondary regional hospitals with over 1200, 1000, and 250 beds each. Other than the smallest ED, the other four EDs were the largest in their counties. The cumulative number of mean annual visits in the five EDs was over 480,000 per year. All adult non-trauma patients who presented to the EDs within the study period were included. Except for the hospital capacity, the five EDs had no difference in services provided, staffing, and equipment. The CT scan was available 24 hours every day in these five EDs.

Study Protocol

All ED patients in the five hospitals were divided into computerized axial tomography (CT) group (patients receiving at least one CT scan during ED stay) and non-CT group (patients without any CT scan during ED stay). Patient demographic factors, including age, sex, visit characteristics (triage category, time of arrival, disposition, ED LOS, and hospital LOS), hospital factors (hospital type and treating physician), and diagnoses were obtained from the ED administrative database and studied in reference to CT utilization. Time of arrival were divided into morning shift (8:00~16:00), evening shift (16:00~00:00), and night shift (00:00~8:00). The dispositions included discharge, admission to observation room then discharge, admission to general ward, admission to ICU, and ED mortality. There were observation rooms in the five EDs of this study. Two kinds of patient were admitted to observation units. First, patients who had no definite diagnosis and were admitted to the observation unit to watch for clinical change. Second, patients who were waiting for hospital admission in the EDs were also admitted to observation units. So, there were some patients in the observation rooms discharged, and others were admitted to the hospital. Patients transferred to other hospitals for admission were categorized as admitted; those discharged against medical advice or outpatient transference were categorized as discharged. Triage category was defined according to the Five Level Taiwan Triage and Acuity Scale, formulated by the Department of Health in Taiwan.

According to these criteria, patients identified as triage levels 1 and 2 should be seen immediately or within 10 minutes, respectively, and are defined as urgent. Patients with triage levels 3, 4, and 5 should be assessed within 30 minutes, 60 minutes, or 120 minutes, respectively, and are classified as non-urgent.[16] Diagnoses were grouped into categories using the diagnostic codes from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

Measures

Patient dispositions and ED LOS were documented as the primary outcomes. The ED LOS was defined from the initial time that the patient presented to the emergency department as documented by the triage nurse to the final time that patient left the ED. ED LOS were calculated in the following five points: discharge from ED, discharge from observation room, admission to general ward, admission to ICU, and ED mortality. The hospital LOS of patient who were admitted to general ward or ICU were documented as secondary outcome to evaluate the prognosis of patient.

Data Analysis

The patient's age, ED LOS and hospital LOS were reported as means with standard deviations (SDs), and analyzed by Student's t test. The distribution of category demographic factors including patient's sex, visit characteristics (triage category, time of arrival), hospital factors (hospital type and treating physician), and diagnoses was presented with number and percentages. Chi-square tests were used to evaluate the association between these parameters and CT scan.

To analyze the influence of CT scan on ED LOS and hospital LOS with adjusting for potential confounding factors including patient's age sex, visit characteristics (triage category, time of arrival), hospital factors (hospital type and treating physician), multiple variable linear regression was applied.

To further reduce the heterogeneity between the study and control group. Propensity score (PS) matching was also used to control for potential confounding factors. The advantage of the PS matching method is the 2-step analysis design, which enables a balance of possible confounding factors between the treated and control groups before "seeing" the results in the 1st step of the analysis. The PS of a patient's probability of receiving CT scan was calculated according to multiple individual characteristics, including patient's age sex, visit characteristics (triage category, time of arrival), hospital factors (hospital type and treating physician) stratified with different diagnosis category via a logistic regression model in the 1st step of the analysis. Different PS matching methods were considered, including exact, sub-classification, nearest neighbor, optimal, and generic matching.[17 18] Nearest neighbor matching without replacement with a ratio of 1: 4 for all diagnosis categories except nervous system disease (1:1) was chosen based on the percent balance improvement, defined as improvement of the mean difference between groups before and after matching. Then, the ED LOS and hospital LOS were compared again between the matching groups with linear regression.

All analyses were 2-tailed and P-values <0.05 were considered statistically significant. SPSS version 12.0 (SPSS, Chicago, IL) and R (version 3.0.2; R Foundation for Statistical Computing, Vienna, Austria) were used for all statistical analyses.

Results

During the one-year study, 293,426 adult non-trauma patients visited the five EDs. Among them, 11.4% of patients received CT scans. Of these patients ongoing CT scan during ED stay, 95.9% received one CT scan, 3.7% received two CT scans, and 0.4% received three or more CT scans. Patient demographic factors, including age, sex, visit characteristics (triage category, time of arrival), hospital factors (hospital type and treating physician), diagnoses, dispositions, ED LOS, and hospital LOS of the two study groups are compared in Table 1. The continuous variables (age, ED LOS, hospital LOS) were analyzed by Student's t-test, and all other category variables were analyzed by $\chi 2$ test. A P value < 0.05 was regarded as statistically significant. The CT scans were most used in diagnoses of nervous system disease (ICD-9-CM: 320–389 and 430–438), followed by gastrointestinal disease (ICD-9-CM: 520–579), genitourinary disease (ICD-9-CM: 580–629), pulmonary disease (ICD-9-CM: 460–519), neoplasms (ICD-9-CM: 140–239), and cardiovascular disease (ICD-9-CM: 390–429 and 439–459). CT scans for these six disease categories accounted for 77.1% of total CT scans in the five EDs.

Table 1 Patients' basic demographic factors

	CT used (33,336)		CT not used (260,090)		P value
Age	60.5	±18.34	53.7	±19.67	<0.001
Sex					
Male	18101	54.3%	129005	49.6%	<0.001
Female	15235	45.7%	131085	50.4%	
Triage					
Urgent	10428	31.3%	42853	16.5%	<0.001
Non-urgent	22908	68.7%	217237	83.5%	
Time of arrival					
8:00~16:00	15172	45.5%	103630	39.8%	<0.001
16:00~00:00	13146	39.4%	102392	39.4%	
00:00~8:00	5018	15.1%	54068	20.8%	
Physician					
Visit staff	21051	63.1%	162100	62.3%	0.003
Resident	12285	36.9%	97990	37.7%	
Hospital					
Center	21523	64.6%	147499	56.7%	<0.001
Region	11813	35.4%	112591	43.3%	
Disposition					
Discharge from ED	8246	24.7%	146539	56.30%	<0.001
Discharge from observation room	6607	19.8%	47831	18.40%	
Admission to general ward	15682	47.0%	58988	22.70%	
Admission to ICU	2557	7.7%	5175	2.00%	
ED mortality	244	0.7%	1557	0.60%	
Diagnostic category					
Nervous	11724	35.2%	25208	9.7%	<0.001
Gastrointestinal	6671	20.0%	61229	23.5%	
Genitourinary	2213	6.6%	25795	9.9%	
Pulmonary	1911	5.7%	44782	17.2%	
Neoplasms	1714	5.1%	10501	4.0%	
Cardiovascular	1456	4.4%	17914	6.9%	
Others	7647	22.9%	74661	28.7%	
ED LOS (hr)	16.6	±27.13	13.0	±27.28	<0.001
Hospital LOS (day)	12.7	14.44	12.5	12.99	<0.001

*Continues variable (age, ED LOS, and hospital LOS) was analyzed by Student's t-test, and all other category variables were analyzed by $\chi 2$ test. A P value < 0.05 was regarded as statistically significant.

In the non-CT group, there were 24.7% patients hospitalized after ED visits (including 22.7% admitted to the general ward and 2.0% to the ICU). In the CT-group, there were 54.7% hospitalized after ED visits (including 47.0% admitted to the general ward and 7.7% to the ICU). The hospitalization rate among patients in the CT group was higher than that of the non-CT group. The overall ED LOS for patients in the CT group was longer than that for patients in the non-CT group (16.6 hours vs. 13.0 hours). However, after stratifying by disposition, patients who discharged from the ED with CT scan tended to have longer ED LOS, while those discharge from the observation room, or admitted to the general ward or ICU had shorter LOS (Fig. 1-A). The hospital LOS for patients admitted to general ward in the CT group was shorter than that for patients in the non-CT group, but the hospital LOS for patients admitted to ICU in the CT group was longer than that for patients in the non-CT group. (Fig. 1-B)

Linear regression was used to analyze the impact of CT on ED LOS and hospital LOS in different diagnostic groups, with adjusting for potential confounding factors, including patient's age sex, visit characteristics (triage category, time of arrival), hospital factors (hospital type and treating physician) in multiple variable regression model (Fig. 2-A, 2-B) and PS matching regression model (Fig. 3-A. 3-B). With regard to patients discharge from the ED, CT prolonged ED LOS in the six diagnostic groups. In patient discharged from the ED, patients had undergone CT scans spent more time in the ED than patients who had not undergone CT scans in all six diagnosis categories in both multiple variable regression model and PS matching regression model. In patients discharged from the observation room, those diagnosed with nervous system disease had shorten ED LOS in both models, but those diagnosed with gastrointestinal disease, pulmonary disease, and cardiovascular disease had prolonged ED LOS after CT scan in the multiple variable regression model but not in the PS matching regression model. Among patients admitted to the general ward, CT use tended to shorten ED LOS, except among those who were diagnosed with cardiovascular disease in multiple variable regression model, but in PS matching regression model, CT use tended to shorten ED LOS in all six diagnose categories. In patients who received CT scans and were then admitted to the ICU, those diagnosed with nervous system disease, neoplasm, and gastrointestinal disease had shorter ED LOS in both models. With regard to hospital LOS in patients admitted to general ward, CT scan tended to shorten hospital LOS in patients diagnosed with nervous system disease, gastrointestinal disease, and genitourinary disease in both models. CT scan

1 did not influence hospital LOS in patient admitted to ICU.

2

Discussion

This study found that the overall rate of CT use in the 5 EDs was 11.4% (12.7% in medical centers and 10.4% in regional hospitals). According to a previous study, approximately 1 in 7 patients with an ED visit underwent a CT scan in the United States by 2007.[12] While there is a trend of increased CT use in the ED, the rate of CT use in this study was somewhat lower than that reported in the United States. The study revealed the CT use was associated with patient's age, sex, time of arrival, clinical urgency, hospital setting, and treating physician. Furthermore, CT use was more prominent among elderly and male patients. Patients visiting the ED with urgent clinical presentation at triage had a greater chance of undergoing CT scans. The reason why patients who visited medical centers were more likely to receive CT scans might be related to clinical complexity. The rate of CT use during evening and night shifts was lower than that during the day shift. This might be because during off-hours of the outpatient clinics, patients visited the ED for relatively non-urgent problems; therefore, there was a lower proportion of CT use.

The CT scan plays an important role in the diagnosis and disposition of patients with acute and sometimes life-threatening illnesses. However, according to a previous study, the indirect effect of CT use may be increased LOS in the ED.[15] Overall, the mean ED LOS for patients who underwent CT scans was longer than that for patients who did not; however, it is over-simplistic to compare the average ED LOS of patients with and without CT scans. According to the study, using CT scan to confirm diagnosis may delay patient discharge by an average of 1.5 hours, but it could accelerate patient admission to the general ward and ICU by an average of 11.5 hours and 7 hours, respectively and it also decreased 1 day of hospital stay in general wards after hospital admission. In the other words, prolonged LOS mainly occurred among patients who were directly discharged from the ED. However, if patients were ever admitted to the observation room before discharge, CT scan shortened the ED LOS in patients with nervous system disease, and in the other five diagnosis categories, there might be no significant difference. When CT scans were utilized, patients diagnosed with nervous system disease, neoplasm, gastrointestinal disease, genitourinary disease, pulmonary disease, and cardiovascular disease who were admitted to the general ward had shorter ED LOS, and those diagnosed with nervous disease, neoplasm, and digestive disease who were admitted to the ICU had shorter ED LOS. In addition to the ED LOS, CT scan in the ED also shortened the total hospital LOS in nervous system disease, gastrointestinal disease, and genitourinary disease after admission to general wards.

The reason why CT scan facilitated patient disposition might be that it shortened the diagnostic process.[13,14] Systermans et al. reported that abdominal CT scans frequently changed the clinical diagnosis and patient disposition.[11] In addition, they also reported that the rate of pulmonary embolism diagnosis in the ED increased significantly along with the increased availability and use of CT.[9] Hoffmann et al. suggested early coronary CT angiography might significantly improve patient management in the ED.[19] According to the study, the acceleration of diagnostic process was more predominant in patients diagnosed with nervous disease. Unlike other diagnostic groups, CT scan not only accelerated these patients admitting to general ward, it also shortened the LOS of these patients to discharge from observation room. According to our clinical experience, some patients presented ED with non-specified neurologic symptoms such as dizziness, vertigo, or headache, and observed in the observation room to wait symptom relived. With CT scan to rule out life threatening condition, physician might be more confident to let patient discharge and it shorten the LOS. Since ED overcrowding is a worldwide problem; thus, it is important to facilitate patient disposition by speeding up the diagnostic process. Conversely, CT use delayed patient discharge from the ED, but without CT to rule out life-threatening problems, more patients might be hospitalized for observation.[12] This further exhausts the limited hospital capacity and exacerbates the issue of ED overcrowding. Furthermore, it is well documented in the literature that between many imaging studies obtained in the emergency department are obtained for medical legal reasons and do not substantively add to the patients diagnosis or care. To improve the diagnostic process, adherence to establish guidelines and best practices would eliminate unnecessary imaging, which would also increase the speed of diagnosis and ED disposition.

Limitations

This study has several limitations. First, the five study sites belonged to the same healthcare system, potentially limiting the implications of the conclusions. For example, the LOS in these ED's is much longer when compared with other ED's around the world and certainly within the US and Western Europe. These differences may be explained by different definitions of observation and differences in the health care economics, patient expectations, or provider practice patterns. This may limit the generalizability of the current study. Second, patients were grouped by ICD-9-CM and not according to the chief complaint. On the other hand, the CT type, including the scan position and use of contrast, was unknown, so it was not possible to evaluate the reasons for CT use in any individual patient. Third, due to the limitations of the retrospective design, there might be some confounding factors not measured in this analysis that could influence patient hospitalization or ED LOS. Further prospective studies are needed to determine the relationship between CT use and patient flow.

Conclusion

According to this study, CT scans seemed not to have delayed patient disposition in ED. While CT scans facilitated patient disposition if they were finally hospitalized, CT scans mildly prolonged ED LOS in patient discharge from the ED.

Figure legend

Figure 1 (A) the emergency department length of stay (hour) and (B) hospital length of stay (day) of different dispositions in the CT and non-CT groups.

Figure 2 The influence of CT scan on (A) emergency department length of stay (hours) and (B) hospital length of stay (day) in different diagnostic groups, adjusting for potential confounding factors, including patient's age, sex, visit characteristics (triage category, time of arrival), and hospital factors (hospital type and treating physician) by multivariable linear regression.

Figure 3 The influence of CT scan on (A) emergency department length of stay (hour) and (B) hospital length of stay (day) in different diagnostic groups, adjusting for potential confounding factors, including patient's age, sex, visit characteristics (triage category, time of arrival), and hospital factors (hospital type and treating physician) by propensity matching linear regression.

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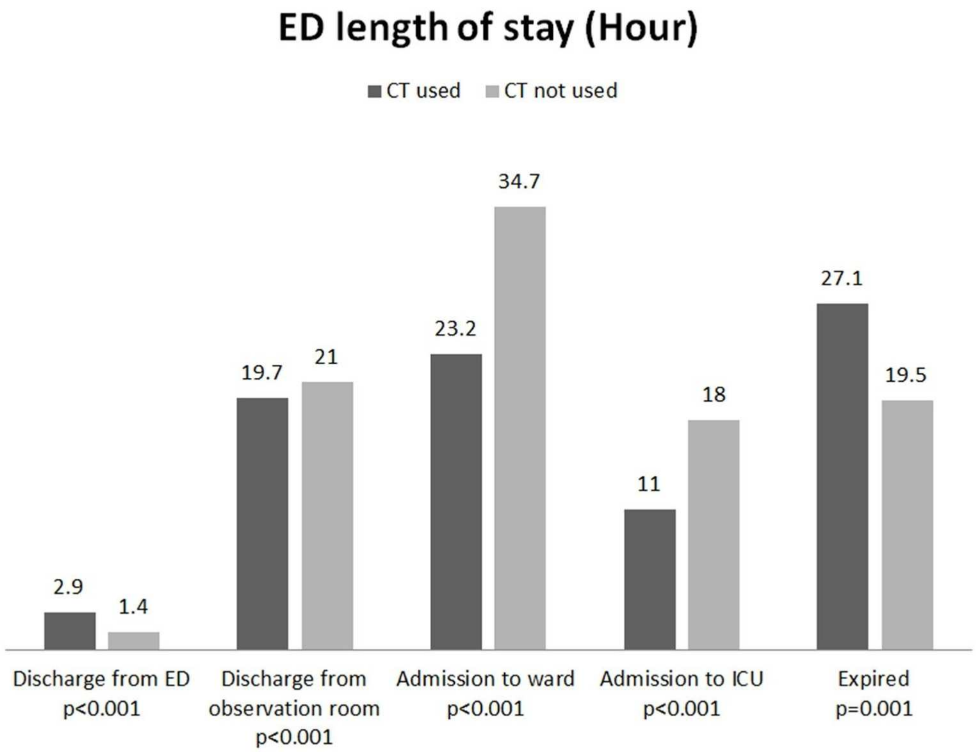

Figure 1-A
117x90mm (300 x 300 DPI)

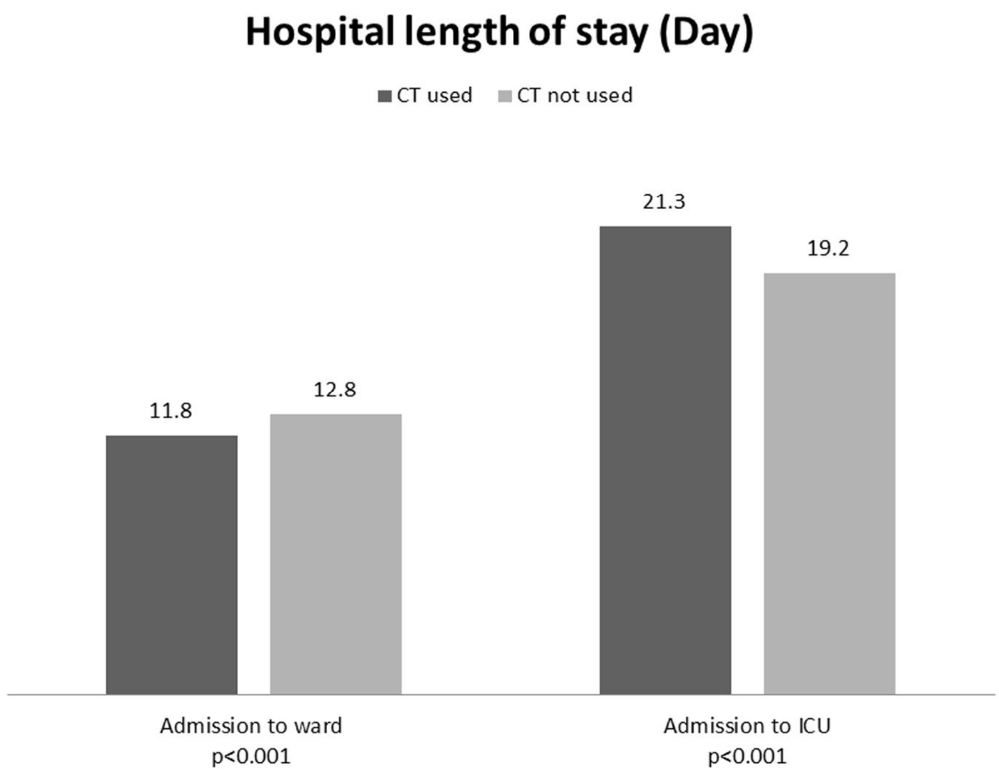

Figure 1-B
115x90mm (300 x 300 DPI)

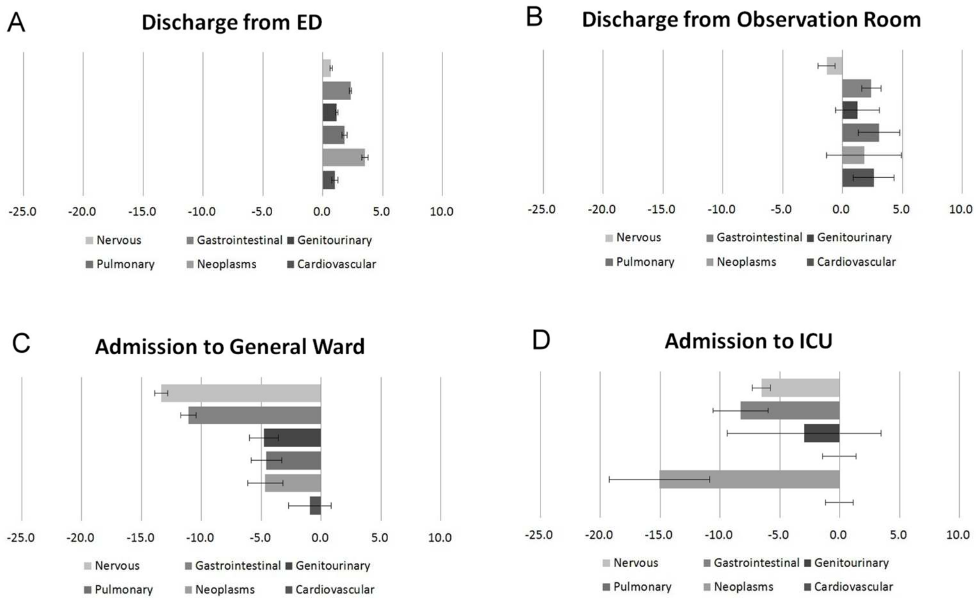

Figure 2-A
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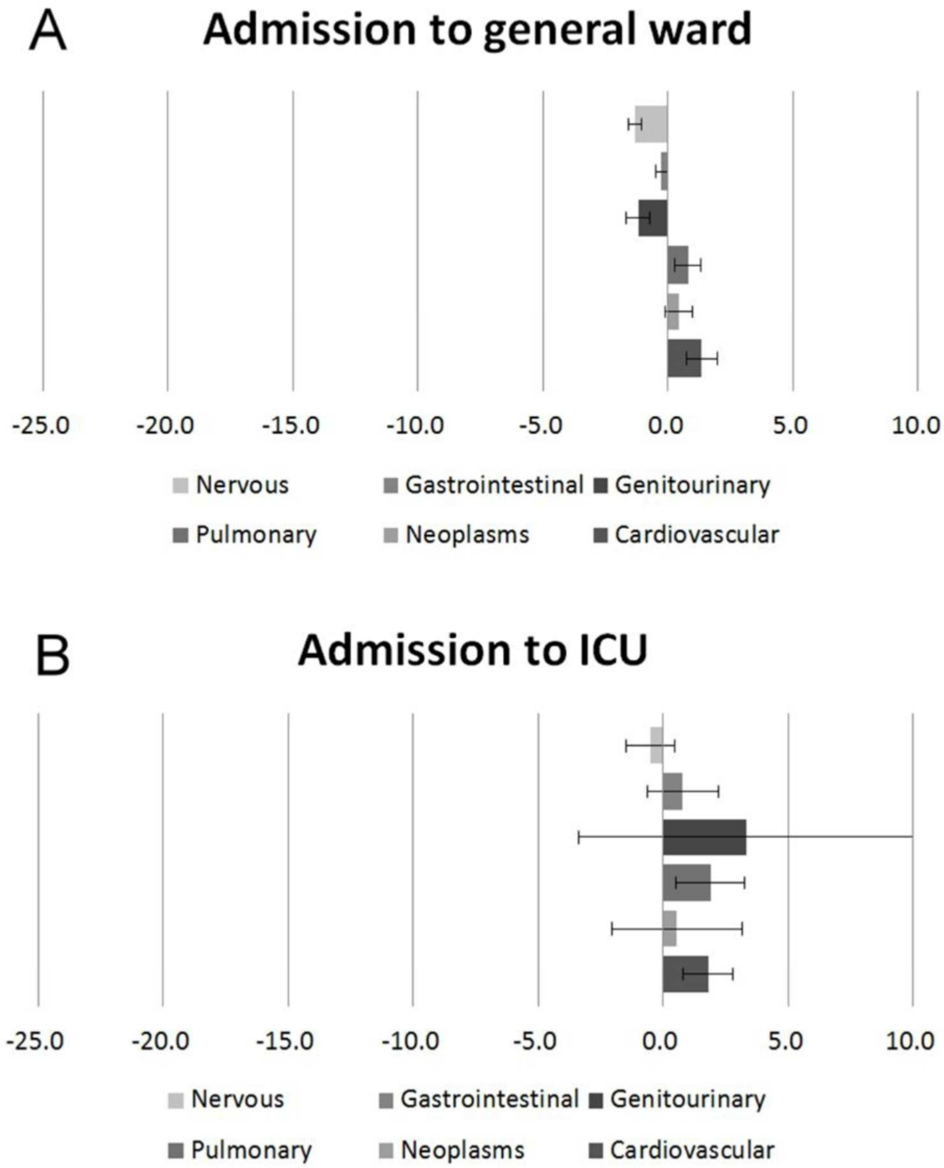

Figure 2-B
72x90mm (300 x 300 DPI)

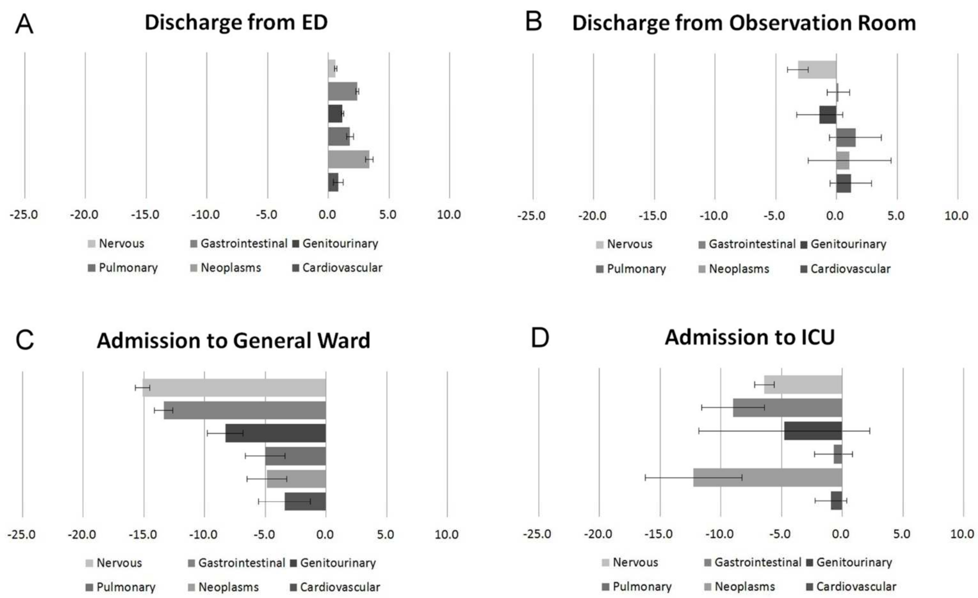

Figure 3-A
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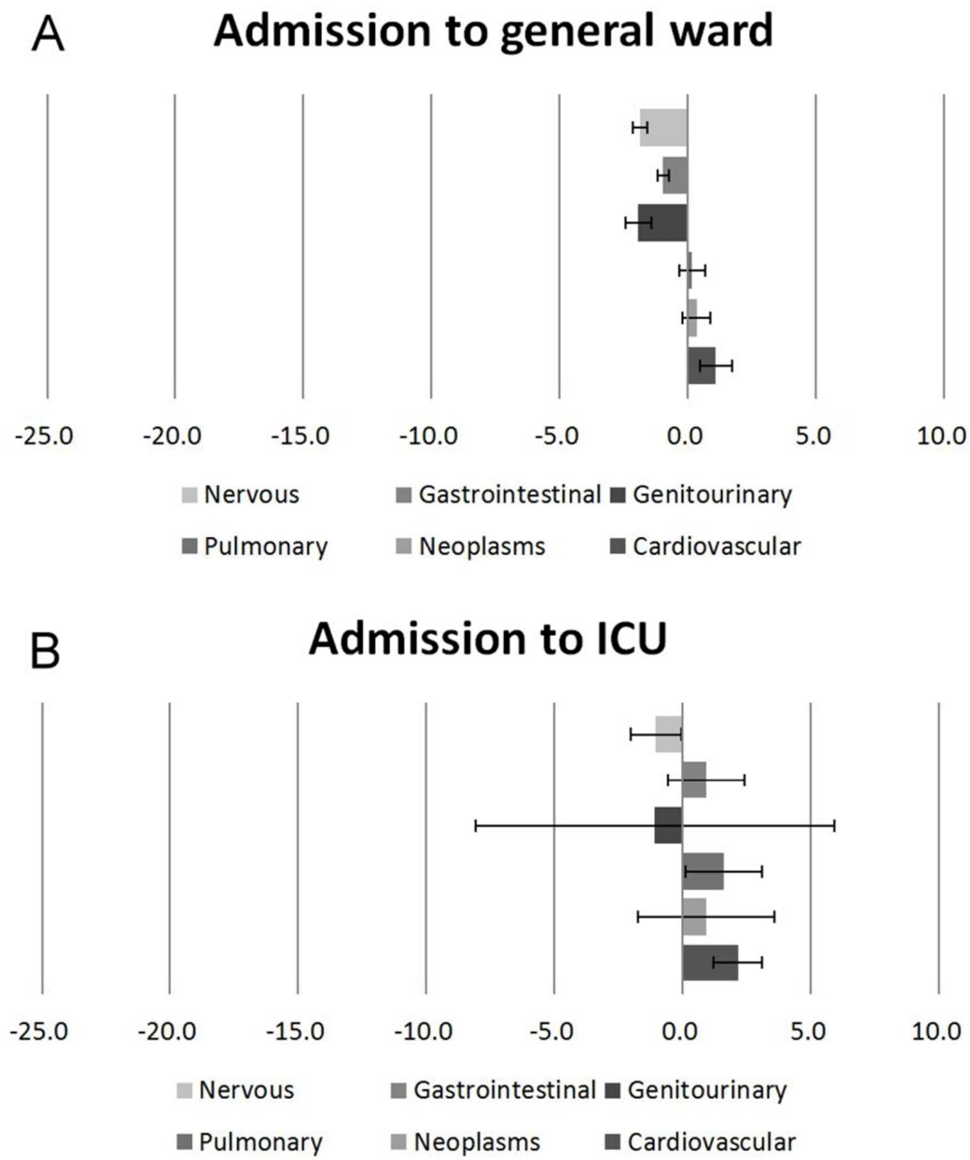

Figure 3-B
75x90mm (300 x 300 DPI)

STROBE Statement

Checklist of items that should be included in reports of observational studies

Section/Topic	Item No	Recommendation	Reported on Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	8
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	10
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Section/Topic	Item No	Recommendation	Reported on Page No
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	13
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	13
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	15
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	15
		(*b*) Report category boundaries when continuous variables were categorized	15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	15
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	15
Discussion			
Key results	18	Summarise key results with reference to study objectives	17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	21
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	23

**Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.*

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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The influence of computed tomography utilization on patient flow in the emergency department: a retrospective one year cohort study

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Secondary Subject Heading:	Radiology and imaging
Keywords:	emergency department, Computed tomography < RADIOLOGY & IMAGING, patient flow, length of stay

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The influence of computed tomography utilization on patient flow in the emergency department, a retrospective one-year cohort study

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All those designated as authors in this work met all four criteria for authorship including 1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work 2) Drafting the work or revising it critically for important intellectual content 3) Final approval of the version to be published and 4) Agreements 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.

Each author are able to identify which co-authors are responsible for specific other parts of the work. In addition, authors have confidence in the integrity of the contributions of their co-authors.

Conflicts of interest statement: no conflict of interest for all authors

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Data sharing statement: No additional data available

Abstract

Objective: Computed tomography (CT), an important diagnostic tool in the emergency department (ED), might increase the ED length of stay (LOS). Considering the issue of ED overcrowding, it is important to evaluate whether CT use delays or facilitates patient disposition in the ED.

Design: A retrospective one-year cohort study.

Setting: Five EDs within the same healthcare system dispersed nationwide in Taiwan.

Participants: All adult non-trauma patients who visited the five EDs from 1 July 2011 to 30 June 2012.

Interventions: Patients were grouped by whether or not they underwent a CT scan (CT and non-CT groups, respectively).

Primary and secondary outcome measures: The ED LOS and hospital LOS between patients who had and had not undergone CT scans were compared by stratifying different dispositions and diagnoses.

Results: CT use prolonged patient ED LOS, among those who were directly discharged from the ED. Among patients admitted to the observation unit and then discharged, patients diagnosed with nervous system disease had shorter ED LOS if they underwent a CT scan. CT use facilitated patient admission to the general ward. CT use also accelerated patients' admission to the intensive care unit (ICU), for

patients with nervous system disease, neoplasm, and digestive disease. Finally, patients admitted to the general wards had shorter hospital LOS if they underwent CT scans in the ED.

Conclusion: CT use did not seem to have delayed patient disposition in ED. While CT use facilitated patient disposition if they were finally hospitalized, it mildly prolonged ED LOS in cases of patients discharged from the ED.

Strengths and limitations of this study

1. This study was conducted across the largest healthcare system in Taiwan, which receives 8–10% of the national health insurance budget according to government statistics. The study sites were geographically well dispersed nationwide.
2. The very large sample size, with 293,426 ED visits, enabled assessment of multiple potential factors to estimate the influence of computed tomography utilization on patient flow in the ED.
3. The study sites belonged to the same healthcare system, potentially limiting the implications of the conclusions.

Introduction

Computed tomography (CT) utilization has grown rapidly due to its recognized clinical value in nearly all areas of medicine, a trend enabled by technologic advances and widespread availability. The utilization of CT scanning in the acute setting nearly tripled from 1996 to 2010.[1] At the same time, the relatively high radiation doses associated with CT have also raised health concerns.[2-4] Multiple factors have contributed to the increase in CT use, such as increased availability and speed of obtaining CT, or possible patient expectations. Whether or not CT scans help disposition of patients in the ED is still controversial. Some studies have stated that CT use might not affect patient outcomes.[5-8] However, other studies have suggested that CT use may reduce the time to disease diagnosis, improve clinical outcome and help patient disposition. For instance, the proportion of ED visits with a diagnosis of pulmonary embolism has increased significantly, and this rise can be attributed in large part to the increased availability and use of CT.[9] Ng et al. reported that early abdominopelvic CT for acute abdominal pain may reduce mortality.[10] Systermans et al. suggested that abdominal CT scans frequently resulted in a change in the clinical diagnosis and patient disposition.[11] Kocher et al. stated that the increased use of CT in the ED was associated with a decline in admissions or transfers.[12] Since ED overcrowding has become an international health issue,[13 14] it is important to evaluate whether use of CT delays or facilitates patient disposition in the ED. However, it is very hard to evaluate the influence of CT use on patient throughput because of several variables that affect patient disposition. A previous study has stated that the indirect effect of CT use may be increased LOS in the ED.[15] It is over-simplistic to compare the average ED LOS of patients who have and have not undergone CT. Therefore, the purpose of this study was to investigate the influence of CT utilization on ED patients' flow with ED LOS as the outcome variable by stratifying patients with different dispositions and diagnoses.

Methods

Study Design

This retrospective one-year cohort study was approved by the Chang Gung Medical Foundation Institutional Review Board. Patient records and information were anonymized and de-identified prior to analysis.

Study Setting and Population

This study was conducted across the largest healthcare system in Taiwan, which receives 8–10% of the national health insurance budget according to government statistics. From 1 July 2011 to 30 June 2012, five EDs within this healthcare system were involved in the study. The five EDs were geographically well dispersed nationwide. Two EDs were tertiary referral medical centers with over 3500 and 2500 beds. The other three were secondary regional hospitals with over 1200, 1000, and 250 beds each. Other than the smallest ED, the other four EDs were the largest in their counties. The cumulative number of mean annual visits in the five EDs was over 480,000 per year. All adult non-trauma patients who presented to the EDs within the study period were included. Except for the hospital capacity, the five EDs had no difference in services provided, staffing, and equipment. The CT scan was available 24 hours every day in these five EDs.

Study Protocol

All ED patients in the five hospitals were divided into computerized axial tomography (CT) group (patients who had undergone at least one CT scan during ED stay) and non-CT group (patients who had not undergone any CT scan during ED stay). Patient demographic factors, including age, sex, visit characteristics (triage category, time of arrival, disposition, ED LOS, and hospital LOS), hospital factors (hospital type and treating physician), and diagnoses were obtained from the ED administrative database and studied in reference to CT utilization. Time of arrival were divided into morning shift (8:00~16:00), evening shift (16:00~00:00), and night shift (00:00~8:00). The dispositions included discharge, admission to the observation room and then discharge, admission to the general ward, admission to the ICU, and ED mortality. There were observation rooms in the five EDs of this study. Two kinds of patients were admitted to the observation units. First, patients who had no definite diagnosis were admitted to the observation unit so that they could be observed for any change in their clinical status. Second, patients who were waiting for hospitalization were also admitted to the observation units. Therefore, some patients in the observation rooms were discharged, and others were admitted to the hospital. Patients transferred to other hospitals for admission were categorized as admitted; those discharged against medical advice or outpatient transference were categorized as discharged. Triage category was defined according to the Five Level Taiwan Triage and Acuity Scale, formulated by the

Department of Health in Taiwan. According to these criteria, cases identified as triage levels 1 and 2 should be attended to immediately or within 10 minutes, respectively, and are defined as urgent. Cases with triage levels 3, 4, and 5 should be assessed within 30 minutes, 60 minutes, or 120 minutes, respectively, and are classified as non-urgent.[16] Diagnoses were grouped into categories using the diagnostic codes from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

Measures

Patient dispositions and ED LOS were documented as the primary outcomes. The ED LOS was defined as the period from the initial presentation of the patient to the ED, as documented by the triage nurse, to the discharge of the patient from the ED. ED LOS were calculated in the following five points: discharge from the ED, discharge from the observation room, admission to the general ward, admission to the ICU, and ED mortality. The hospital LOS of patients who were admitted to the general ward or ICU were documented as secondary outcomes to evaluate the prognosis of patients.

Data Analysis

The patient age, ED LOS, and hospital LOS were reported as means with standard deviations (SDs), and analyzed by Student's t test. The distribution of category demographic factors including patient sex, visit characteristics (triage category, time of arrival), hospital factors (hospital type and treating physician), and diagnoses was presented as numbers and percentages. Chi-square tests were used to evaluate the association between these parameters and CT utilization.

To analyze the influence of CT utilization on ED LOS and hospital LOS, multivariable linear regression was applied after adjusting for potential confounding factors including patient age and sex, visit characteristics (triage category, time of arrival), and hospital factors (hospital type and treating physician).

To further reduce the heterogeneity between the study and control group, propensity score (PS) matching was also used to control for potential confounding factors. The advantage of the PS matching method is the 2-step analysis design, which enables a balance of possible confounding factors between the treated and control groups before "seeing" the results in the 1st step of the analysis. The PS of a patient's probability of undergoing a CT scan was calculated according to multiple individual characteristics, including patient age and sex, visit characteristics (triage category, time of arrival), and hospital factors (hospital type and treating physician) stratified with different diagnosis categories via a logistic regression model in the 1st step of the analysis. Different PS matching methods were considered, including exact, sub-classification, nearest neighbor, optimal, and generic matching.[17 18] Nearest neighbor matching without replacement with a ratio of 1: 4 for all diagnosis categories except nervous system disease (1:1) was chosen based on the percent balance improvement, defined as improvement of the mean difference between groups before and after matching. Then, the ED LOS and hospital LOS were compared again between the matching groups with linear regression.

All analyses were 2-tailed and P-values <0.05 were considered statistically significant. SPSS version 12.0 (SPSS, Chicago, IL) and R (version 3.0.2; R Foundation for Statistical Computing, Vienna, Austria) were used for all statistical analyses.

Results

During the one-year study, 293,426 adult non-trauma patients visited the five EDs. Among them, 11.4% of patients underwent CT scans. Of these patients ongoing a CT scan during the ED stay, 95.9% underwent one CT scan, 3.7% underwent two CT scans, and 0.4% underwent three or more CT scans. Patient demographic factors, including age, sex, visit characteristics (triage category, time of arrival), hospital factors (hospital type and treating physician), diagnoses, dispositions, ED LOS, and hospital LOS of the two study groups are compared in Table 1. The continuous variables (age, ED LOS, hospital LOS) were analyzed by Student's t-test, and all other category variables were analyzed by $\chi2$ test. The CT scans were most frequently used in the diagnoses of nervous system disease (ICD-9-CM: 320–389 and 430–438), followed by gastrointestinal disease (ICD-9-CM: 520–579), genitourinary disease (ICD-9-CM: 580–629), pulmonary disease (ICD-9-CM: 460–519), neoplasms (ICD-9-CM: 140–239), and cardiovascular disease (ICD-9-CM: 390–429 and 439–459). CT scans for these six disease categories accounted for 77.1% of the total CT scans performed in the five EDs.

1 **Table 1** Patients' basic demographic factors

	CT used (33,336)		CT not used (260,090)		P value
Age	60.5	±18.34	53.7	±19.67	<0.001
Sex					
Male	18101	54.3%	129005	49.6%	<0.001
Female	15235	45.7%	131085	50.4%	
Triage					
Urgent	10428	31.3%	42853	16.5%	<0.001
Non-urgent	22908	68.7%	217237	83.5%	
Time of arrival					
8:00~16:00	15172	45.5%	103630	39.8%	<0.001
16:00~00:00	13146	39.4%	102392	39.4%	
00:00~8:00	5018	15.1%	54068	20.8%	
Physician					
Visit staff	21051	63.1%	162100	62.3%	0.003
Resident	12285	36.9%	97990	37.7%	
Hospital					
Center	21523	64.6%	147499	56.7%	<0.001
Region	11813	35.4%	112591	43.3%	
Disposition					
Discharge from ED	8246	24.7%	146539	56.30%	<0.001
Discharge from observation room	6607	19.8%	47831	18.40%	
Admission to general ward	15682	47.0%	58988	22.70%	
Admission to ICU	2557	7.7%	5175	2.00%	
ED mortality	244	0.7%	1557	0.60%	
Diagnostic category					
Nervous	11724	35.2%	25208	9.7%	<0.001
Gastrointestinal	6671	20.0%	61229	23.5%	
Genitourinary	2213	6.6%	25795	9.9%	
Pulmonary	1911	5.7%	44782	17.2%	
Neoplasms	1714	5.1%	10501	4.0%	
Cardiovascular	1456	4.4%	17914	6.9%	
Others	7647	22.9%	74661	28.7%	
ED LOS (hr)	16.6	±27.13	13.0	±27.28	<0.001
Hospital LOS (day)	12.7	14.44	12.5	12.99	<0.001

2 *Continues variables (age, ED LOS, and hospital LOS) were analyzed by Student's

t-test, and all other category variables were analyzed by $\chi 2$ test. A P value < 0.05 was regarded as statistically significant.

In the non-CT group, 24.7% patients were hospitalized after ED visits (including 22.7% admitted to the general ward and 2.0% admitted to the ICU). In the CT-group, 54.7% of the patients were hospitalized after ED visits (including 47.0% admitted to the general ward and 7.7% admitted to the ICU). The hospitalization rate among patients in the CT group was higher than that among patients in the non-CT group. The overall ED LOS for patients in the CT group was longer than that for patients in the non-CT group (16.6 hours vs. 13.0 hours). However, after stratifying by disposition, patients who were discharged from the ED and who had undergone a CT scan tended to have longer ED LOS, while those discharged from the observation rooms or who were admitted to the general ward or ICU had shorter LOS (Fig. 1-A). The hospital LOS for patients in the CT group who were admitted to the general ward was shorter than that for patients in the non-CT group, but the hospital LOS for patients in the CT group who were admitted to the ICU was longer than that for patients in the non-CT group (Fig. 1-B).

Linear regression was used to analyze the impact of CT on ED LOS and hospital LOS in different diagnostic groups, after adjusting for potential confounding factors, including patient age and sex, visit characteristics (triage category, time of arrival), and hospital factors (hospital type and treating physician) in the multivariable regression model (Fig. 2-A, 2-B) and PS matching regression model (Fig. 3-A. 3-B). With regard to patients discharged from the ED, CT prolonged ED LOS in the six diagnostic groups. Among patients discharged from the ED, patients who had undergone CT scans spent more time in the ED than patients who had not undergone CT scans in all six diagnosis categories in both the multivariable regression model and the PS matching regression model. Among patients discharged from the observation room, those diagnosed with nervous system disease had shorter ED LOS in both models, but those diagnosed with gastrointestinal disease, pulmonary disease, and cardiovascular disease had prolonged ED LOS after undergoing CT scan, in the multivariable regression model but not in the PS matching regression model. Among patients admitted to the general ward, CT use tended to shorten ED LOS, except among those who were diagnosed with cardiovascular disease, in the multivariable regression model; however, in the PS matching regression model, CT use tended to shorten ED LOS in all six diagnose categories. Among patients who underwent CT scans and were then admitted to the ICU, those diagnosed with nervous system disease, neoplasm, and gastrointestinal disease had shorter ED LOS in both models. With regard to hospital LOS among patients admitted to the general ward, CT use tended to shorten hospital LOS in patients diagnosed with nervous system disease, gastrointestinal disease, and genitourinary disease in both models. CT scan use did not influence hospital LOS among patients admitted to the ICU.

Discussion

This study found that the overall rate of CT use in the 5 EDs was 11.4% (12.7% in medical centers and 10.4% in regional hospitals). According to a previous study, approximately 1 in 7 patients with an ED visit underwent a CT scan in the United States by 2007.[12] While there is a trend of increased CT use in the ED, the rate of CT use in this study was somewhat lower than that reported in the United States. The study revealed that CT use was associated with patient age and sex, time of arrival, clinical urgency, hospital setting, and treating physician. Furthermore, CT use was more prominent among elderly and male patients. Patients visiting the ED with urgent clinical presentation at triage had a greater chance of undergoing CT scans. The reason why patients who visited medical centers were more likely to receive CT scans might be related to clinical complexity. The rate of CT use during evening and night shifts was lower than that during the day shift. This might be because during off-hours of the outpatient clinics, patients visited the ED for relatively non-urgent problems; therefore, there was a lower proportion of CT use.

CT plays an important role in the diagnosis and disposition of patients with acute and sometimes life-threatening illnesses. However, according to a previous study, the indirect effect of CT use may be increased LOS in the ED.[15] Overall, the mean ED LOS for patients who underwent CT scans was longer than that for patients who did not; however, it is over-simplistic to compare the average ED LOS of patients who have and have not undergone CT scans. According to the study, using CT scan to confirm diagnosis may delay patient discharge by an average of 1.5 hours, but it could accelerate patient admission to the general ward and ICU by an average of 11.5 hours and 7 hours, respectively; moreover, it decreased 1 day of hospital stay in general wards after hospital admission. In other words, prolonged LOS mainly occurred among patients who were directly discharged from the ED. However, if patients were ever admitted to the observation room before discharge, CT use shortened the ED LOS in patients with nervous system disease, and no significant difference was noted for the other five diagnosis categories. When CT scans were utilized, patients diagnosed with nervous system disease, neoplasm, gastrointestinal disease, genitourinary disease, pulmonary disease, and cardiovascular disease, who were admitted to the general ward, had shorter ED LOS, and those diagnosed with nervous disease, neoplasm, and digestive disease, who were admitted to the ICU, had shorter ED LOS. In addition to the ED LOS, CT scan in the ED shortened the total hospital LOS in nervous system disease, gastrointestinal disease, and genitourinary disease after admission to general wards.

The reason why CT scan facilitated patient disposition might be that it shortened the diagnostic process.[13,14] Systermans et al. reported that abdominal CT scans frequently changed the clinical diagnosis and patient disposition.[11] In addition, they reported that the rate of pulmonary embolism diagnosis in the ED increased significantly along with the increased availability and use of CT.[9] Hoffmann et al. suggested early coronary CT angiography might significantly improve patient management in the ED.[19] According to the study, the acceleration of diagnostic process was more predominant in patients diagnosed with nervous disease. Unlike other diagnostic groups, CT use not only accelerated these patients admitting to the general ward, but also shortened the LOS of patients who were discharged from the observation room. According to our clinical experience, some patients presented to the ED with non-specified neurologic symptoms such as dizziness, vertigo, or headache without obvious focal neurologic deficit and only observed in the observation room to wait symptom relived. When life-threatening conditions can be ruled out based on the CT findings, physicians might be more confident to allow patient discharge, which will shorten the LOS. ED overcrowding is a worldwide problem; thus, it is important to facilitate patient disposition by speeding up the diagnostic process. Conversely, CT use delayed patient discharge from the ED, but without CT to rule out life-threatening problems, more patients might be hospitalized for observation.[12] This further exhausts the limited hospital capacity and exacerbates the issue of ED overcrowding. To improve the diagnostic process, adherence to establish guidelines and best practices would increase the speed of diagnosis and ED disposition.

Limitations

This study has several limitations. First, the five study sites belonged to the same healthcare system, potentially limiting the implications of the conclusions. For example, the LOS in these EDs is much longer than those in other EDs worldwide and certainly within EDs in the US and Western Europe. These differences may be explained by different definitions of observation and differences in the health care economics, patient expectations, or provider practice patterns. This may limit the generalizability of the current study. Second, patients were grouped by ICD-9-CM and not according to the chief complaint. On the other hand, the CT type, including the scan position and use of contrast, was unknown; hence, it was not possible to evaluate the reasons for CT use in any individual patient. Third, due to the limitations of the retrospective design, there might be some confounding factors that were not measured in this analysis that could influence patient hospitalization or ED LOS. Further prospective studies are needed to determine the relationship between CT use and patient flow.

Conclusion

According to this study, CT scans did not seem to have delayed patient disposition in ED. While CT use facilitated patient disposition if patients were finally hospitalized, it mildly prolonged ED LOS for patients discharged from the ED.

Figure legend

Figure 1 (A) the emergency department length of stay (hour) and (B) hospital length of stay (day) of different dispositions in the CT and non-CT groups.

Figure 2 The influence of CT utilization on (A) emergency department length of stay (hours) and (B) hospital length of stay (day) in different diagnostic groups, adjusting for potential confounding factors, including patient's age, sex, visit characteristics (triage category, time of arrival), and hospital factors (hospital type and treating physician) by multivariable linear regression.

Figure 3 The influence of CT utilization on (A) emergency department length of stay (hour) and (B) hospital length of stay (day) in different diagnostic groups, adjusting for potential confounding factors, including patient's age, sex, visit characteristics (triage category, time of arrival), and hospital factors (hospital type and treating physician) by propensity matching linear regression.

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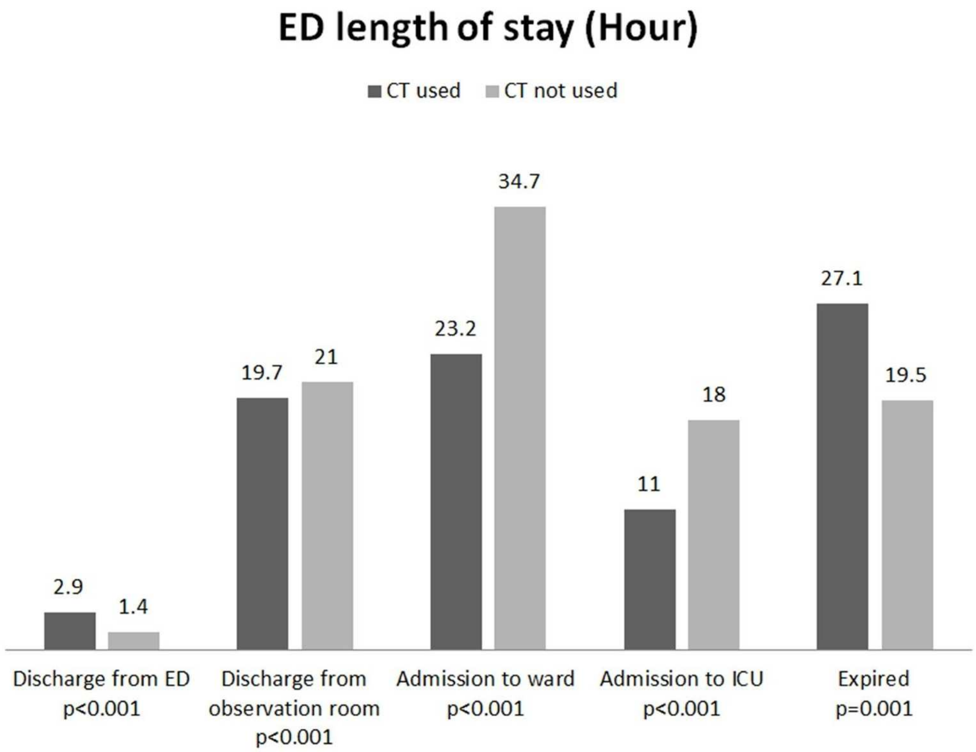

Figure 1-A
117x90mm (300 x 300 DPI)

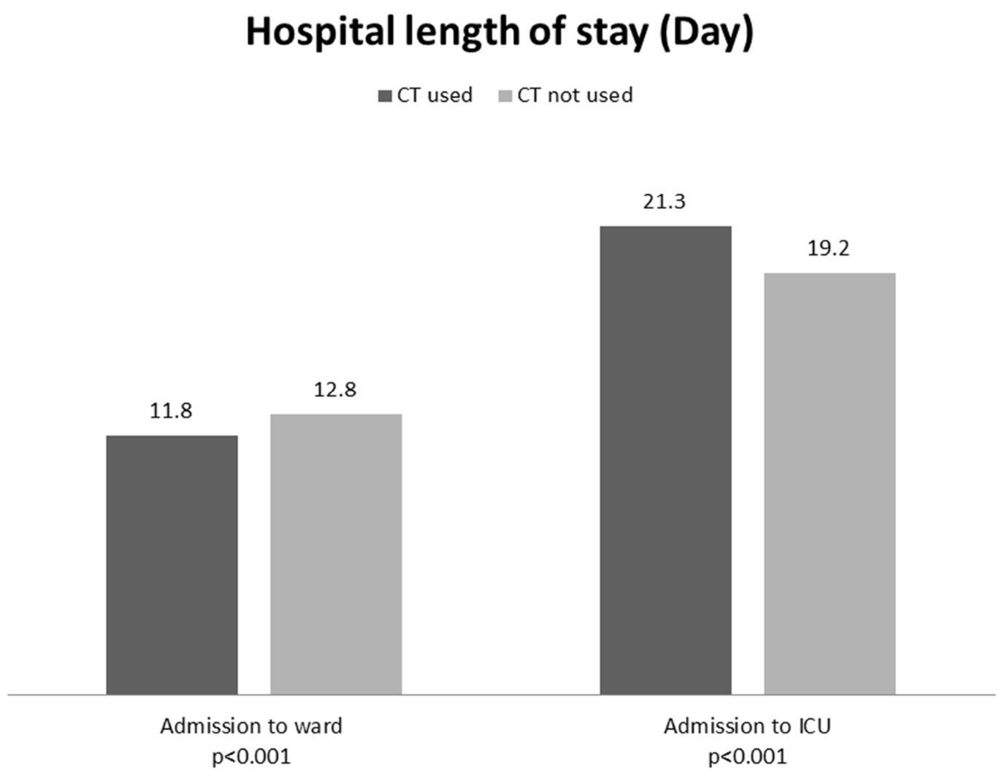

Figure 1-B
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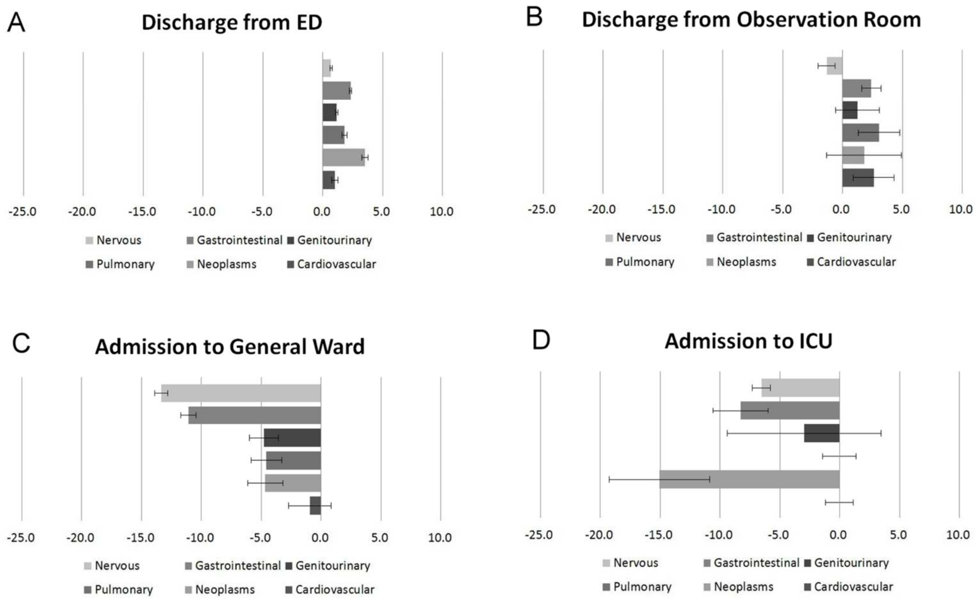

Figure 2-A
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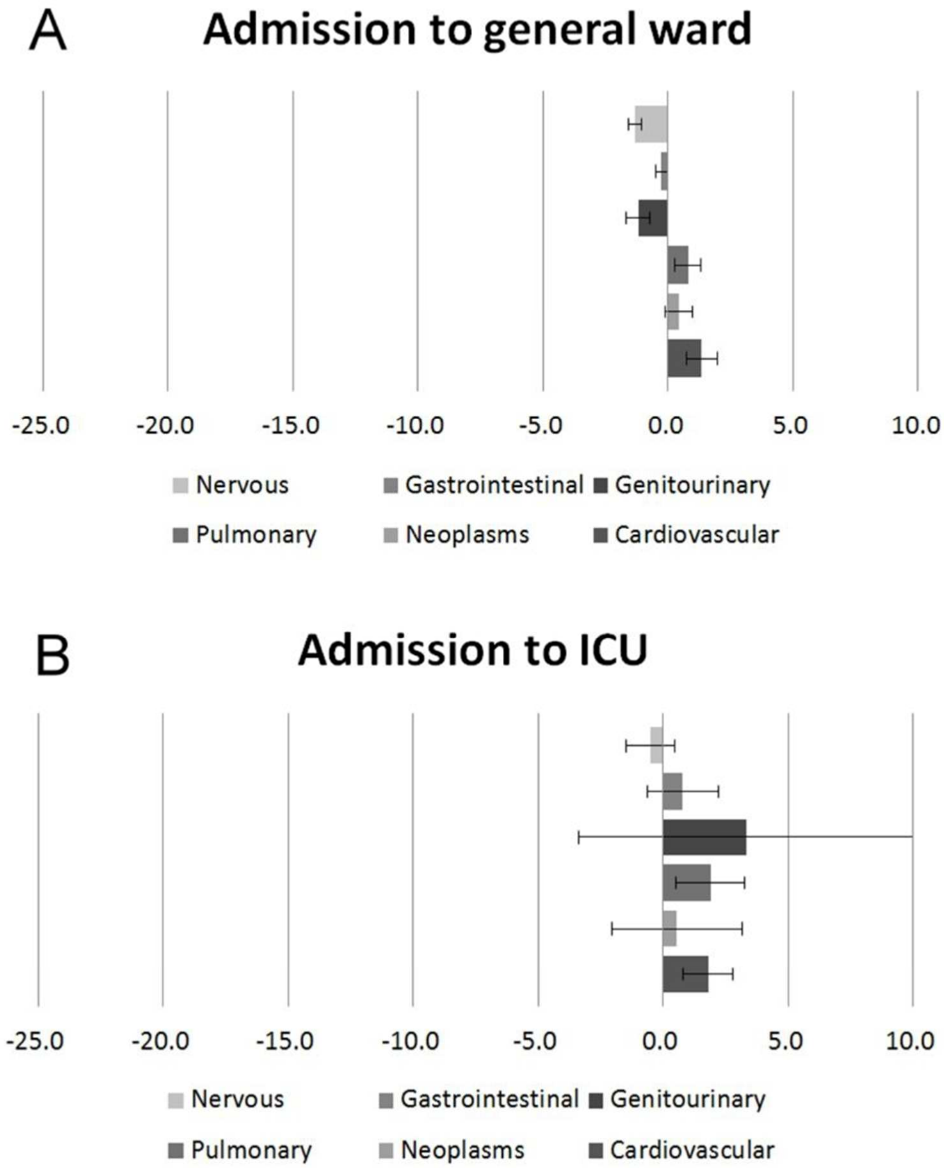

Figure 2-B
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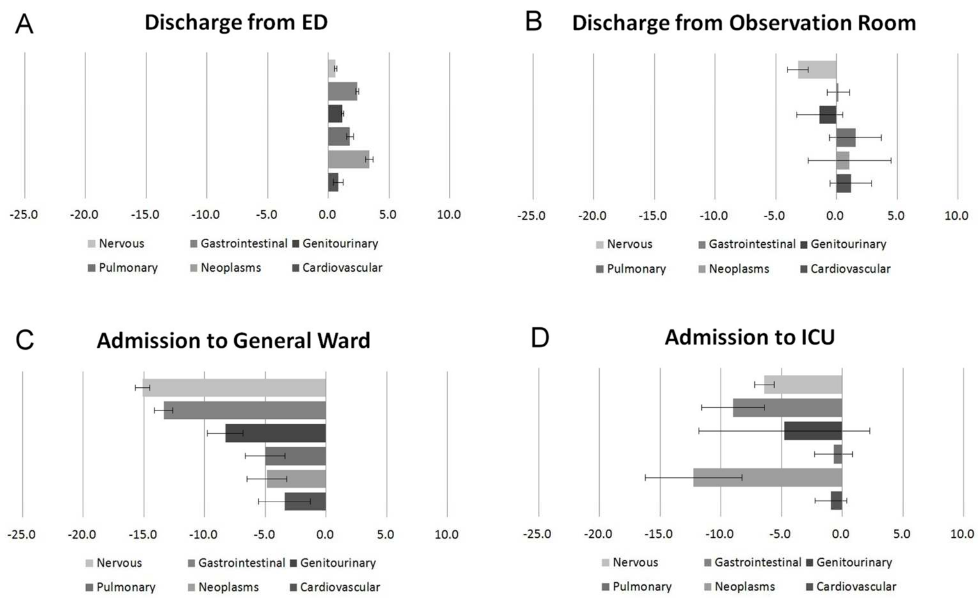

Figure 3-A
151x90mm (300 x 300 DPI)

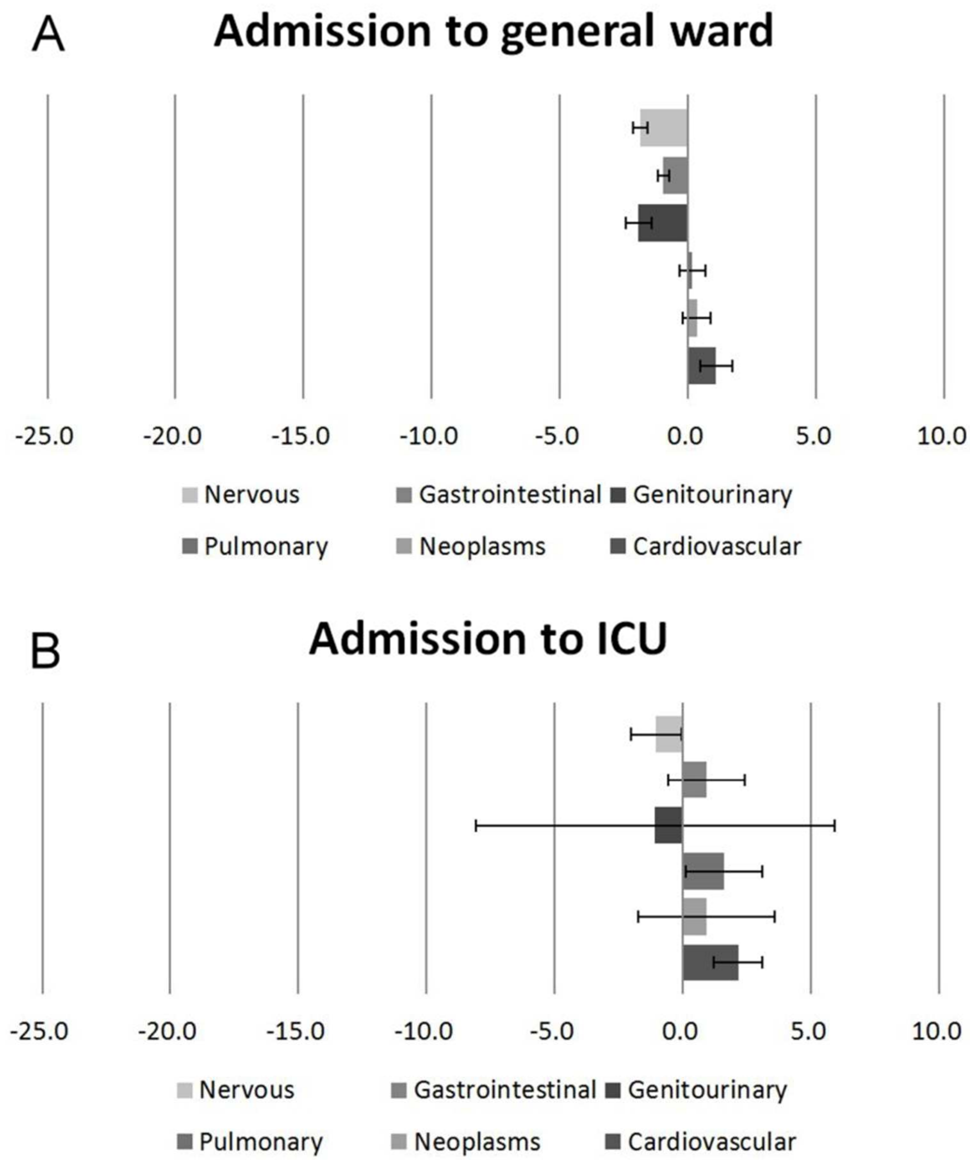

Figure 3-B
75x90mm (300 x 300 DPI)

STROBE Statement

Checklist of items that should be included in reports of observational studies

Section/Topic	Item No	Recommendation	Reported on Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	8
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	10
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Section/Topic	Item No	Recommendation	Reported on Page No
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	13
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	13
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	15
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	15
		(*b*) Report category boundaries when continuous variables were categorized	15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	15
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	15
Discussion			
Key results	18	Summarise key results with reference to study objectives	17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	21
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	23

**Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.*

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.