Supplementary Online Content

Li HM, Liu SZ, Yeh LR, et al: Trends of computed tomography use in a tertiary emergency department in Taiwan from 2010 to 2020. E-Da Med J 2024;11:9-19. doi:10.6966/EDMJ.202406_11(2).0002

eTable 1. STROBE Statement – checklist of items that should be included in reports of observational studies.
eTable 2. Trends of any CT use in the ED patients (presenting in annual ASR per 1,000 ED visit) during 2010 – 2020, with age, sex, triage, and trauma stratification.

eFig. 1 The proportion of each type of CT in all ED CT studies, 2010 – 2020.
eFig. 2 Trends of age-standardized rate (ASR) in repeat CT imaging per 1,000 ED visits, stratified by (A) age, (B) sex, (C) triage and (D) trauma subgroups.

This supplementary material has been provided by the authors to give readers additional information about their work.

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eTable 1. STROBE Statement—checklist of items that should be included in reports of observational studies.

	Item No.	Recommendation	Page No.	Relevant text from manuscript
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2	To analyze the trends of computed tomography (CT) use and repeat CT imaging in a tertiary emergency department (ED) in Taiwan.
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2	**AIM:** To analyze the trends of computed tomography (CT) use and repeat CT imaging in a tertiary emergency department (ED) in Taiwan. **MATERIALS AND METHODS:** From 719,670 records of ED visits during 2010 – 2020, we calculated annual crude rates and age-standardized rates (ASRs) of any CT use (per 1,000 ED visits) with corresponding average annual percent changes (AAPCs) and 95% confidence intervals (95% CIs). We also calculated the above rates and AAPCs for repeat CT and each CT type. Using ASRs and AAPCs could minimize the confounding effect of aging and provide a stable comparison of trends. **RESULTS:** The ASR of any CT use increased from 107.7 (95% CI 105.2 – 110.3) in 2010 to 173.6 (95% CI 169.9 – 177.3) in 2020, with an AAPC of 3.9 (95% CI 3.4 – 4.5). Consistent results were found for repeat CT and each CT type, with the highest AAPC in spine CT (28.2, 95% CI 26.4 – 31.1), followed by extremity CT (19.6, 95% CI 16.2 – 24.2). Brain CT had the lowest AAPC (0.9, 95% CI 0.1 – 1.7). The increase in ASR was associated with older age, being male, more emergent acuity, and trauma. Upward trends of ASRs were observed in most subgroups, except for the pediatric and non-urgent subgroups. **CONCLUSION:** Increasing trends of CT use and repeat CT imaging were found in a tertiary ED in Taiwan during 2010 – 2020, even after age standardization with the general population. Marked growth of spine and extremity CT use was also observed. Further investigation is needed to evaluate potential CT overuse in ED.

Introduction				
Background/ rationale	2	Explain the scientific background and rationale for the investigation being reported	3 – 4	Computed tomography (CT) has played a vital role in the emergency department (ED) for rapid diagnosis and triage of patients. Although the use of brain CT in stroke and traumatic brain injury is well-known, clinical guidelines have offered more indications for CT in the last decade, such as polytrauma, major bleeding, cervical spine clearance, acute chest pain, peripheral artery disease, small bowel obstruction, urolithiasis, and therefore extended CT use in the ED. In the United States (US), the reported rates of CT use per ED visit increased nearly 5-fold between 1995 and 2007, from 2.8% to 13.9%. Similar growth has been reported in several countries, raising concerns about CT overuse worldwide. The universal coverage of National Health Insurance (NHI) in Taiwan facilitated the use of high-cost medical imaging such as CT and magnetic resonance imaging (MRI), which may lead to possible CT overuse in ED patients causing excessive radiation exposure and healthcare cost. However, there is no consensus on the definition and measurement of CT overuse. A systematic review of imaging overuse in ED described two definitions of CT overuse: repeat imaging and inappropriate imaging without sufficient justification. The latter definition is subjectively evaluated and difficult to apply to large samples. In this study, we use repeat CT imaging as a surrogate of CT overuse, and the term of "CT use" refers to CT examinations in an ED visit, not including those in the subsequent hospitalization. The growth magnitude and temporal trends of CT use vary depending on imaging types, study periods, patient characteristics, hospital settings, and countries. Therefore, continuous and comprehensive monitoring of CT use is necessary to determine the presence of CT overuse and identify potential areas for control measures. However, most trend reports of CT use have originated from Western countries, whereas Asian data remains outdated and underreported. In addition, global aging has been known for increased healthcare utilization. Previous studies have shown the association between age and CT use, but rarely used age-standardized rates (ASRs) in trend comparison to adjust for aging confounding.
Objectives	3	State specific objectives, including any prespecified hypotheses	4	This study aimed to assess the trends of CT use and repeat CT imaging in a tertiary ED in Taiwan using ASRs, which could minimize the confounding effect of aging, and make our data comparable with those from the general population.
Methods				
Study design	4	Present key elements of study design early in the paper	4	This retrospective observational study was conducted during 2010 – 2020 at a 1,259-bed tertiary referral hospital in Taiwan.
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4	This retrospective observational study was conducted during 2010 – 2020 at a 1,259-bed tertiary referral hospital in Taiwan, with the capabilities of a Level I Trauma Center and an average of 66,000 ED visits per year. The ED had full access to two multi-detector CT scanners located next door (Brightspeed Elite 16, GE Healthcare, Buckinghamshire, United Kingdom; SOMATOM Sensation 16, Siemens, Erlangen, Germany). Board-certificated radiologists provided 24-hour reporting services with night shifts.

Participants	6	(a) Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants	4	We enrolled all patient records of ED visits during 2010 – 2020 but excluded visits with incomplete data (n = 473), visits for documentation or certification (n = 6,927), and visits involving patients who were dead on arrival with unsuccessful resuscitation (n = 1,644). Figure 1 illustrates the patient selection diagram.
		(b) Cohort study—For matched studies, give matching criteria and number of exposed and unexposed		Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5	Measurements of CT use We used annual crude rates and ASRs of ED visits involving any CT use (per 1,000 ED visits) to assess the trends of CT use. The annual crude rates were calculated on a comparable basis to previous studies,10 – 16 as the number of CT users divided by the number of total ED visits in each year. The annual ASRs were calculated from crude rates by applying direct standardization with the age distribution of Taiwan's population in 2010. The reasons for using ASRs were to reduce the confounding effect of aging on the study population and to facilitate comparability of the results to the general population. We also calculated the above rates of ED visits involving repeat CT imaging and each CT type. Repeat CT imaging was measured dichotomously as whether the patient was transferred with CT imaging in the previous hospital or had multiple CT scans during the same ED visit. CT types were grouped by anatomical sites applied for scanning as follows: brain (including the brain and sella turcica), neck (including the facial bone, temporal bone, nasopharynx, and neck), chest (including the chest, heart, aorta, and pulmonary artery), abdomen (including the abdomen and pelvis), extremity (including upper and lower limbs), and spine (including cervical, thoracic, lumbar, and sacral spine). All rates are presented with corresponding 95% confidence intervals (95% CIs). Potential associated factors To explore factors associated with trends of CT use, we collected patient demographics (age and sex) and characteristics of ED visits (triage score and trauma status). Patient ages were grouped into five categories: < 18 years, 18 – 34 years, 35 – 54 years, 55 – 74 years, and ≥ 75 years. Triage scores were evaluated by the Taiwan Triage and Acuity Scale, then collapsed into three categories (emergent: triage score 1 or 2; urgent: triage score 3; non-urgent: triage score 4 or 5) to increase statistical power. Trauma status was categorized dichotomously as yes or no.

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	5	As the above
Bias	9	Describe any efforts to address potential sources of bias	6	To quantify the temporal trends of annual crude rates and ASRs, we estimated their average annual percent changes (AAPCs) with 95% CIs for the study period (i.e., 2010 – 2020). AAPC is a weighted average of the annual percent changes from the joinpoint regression model with the best fit for the data, with weights equal to the length of each trend segment. Compared to the conventional method of calculating the compound annual growth rate, which assumes the linearity of a single trend between two time points, the AAPC method with joinpoint regression analyses reflects serial trends in the study period, which is advantageous when the data are sparse and short trend segments are present. AAPC has been proven to be a good summary measure of trends, which provides a stable comparison across different groups and time intervals with minimal framing bias. Significant AAPC with 95% CI above and below zero indicates upward and downward trends, respectively, whereas non-significant AAPC with 95% CI containing zero indicates stable trends. We performed subgroup analyses stratified by age, sex, triage, and trauma to compare ASR and AAPC trends for each type of CT. The reason for choosing ASRs to compare trends was to reduce the confounding effect of aging on the study population.
Study size	10	Explain how the study size was arrived at	7	A total of 716,970 ED visits were included in this study.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5 – 6	We categorized ED patients into five age groups: < 18 years, 18 – 34 years, 35 – 54 years, 55 – 74 years, and ≥ 75 years. Triage scores were assessed using the 5-level Taiwan Triage and Acuity Scale, then collapsed into three groups to increase statistical power, comprising emergent (triage score 1 or 2), urgent (triage score 3), and non-urgent (triage score 4 or 5) cases.

Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	6	Descriptive statistics were used to summarize patient demographics, visit characteristics, and CT use across study periods. Trend tests for variables of interest were performed using linear regression for parametric continuous variables, the Jonckheere-Terpstra Test for non-parametric continuous variables, the Cochran-Armitage Trend Test for binary categorical variables, and the Cochran-Mantel-Haenszel Test for multi-level categorical variables. To quantify the temporal trends of annual crude rates and ASRs, we estimated their average annual percent changes (AAPCs) with 95% CIs for the study period (i.e., 2010 – 2020). The AAPC, obtained from the joinpoint regression model with the best fit for the data, is a weighted average of the annual percent changes according to the length of each trend segment. AAPC has been proven to be a good summary measure of trends with minimal framing bias, especially when data are sparse and short trend segments are present. It could provide a stable comparison across different groups and time intervals. An AAPC with 95% CI above and below zero indicates upward and downward trends, respectively, while an AAPC with 95% CI containing zero indicates stable trends.
		(b) Describe any methods used to examine subgroups and interactions	6	Subgroup analyses stratified by age, sex, triage, and trauma status were conducted to compare ASR and AAPCs.
		(c) Explain how missing data were addressed	4	Subjects with incomplete data were excluded.
		(d) Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	5	The annual ASRs were calculated from crude rates by applying direct standardization with the age distribution of Taiwan's population in 2010. The reasons for using ASRs were to reduce the confounding effect of aging on the study population and to facilitate comparability of the results to the general population.
		(e) Describe any sensitivity analyses		Not applicable
Results				
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, included in the study, completing follow-up, and analysed	4	We enrolled all patient records of ED visits during 2010 – 2020. The exclusion criteria for ED visits were as follows: incomplete data (n = 473), visits for documentation or certification (n = 6,927), and visits involving patients who were dead on arrival with unsuccessful resuscitation (n = 1,644). Figure 1 illustrates the patient selection diagram.
		(b) Give reasons for non-participation at each stage	4	As the above
		(c) Consider use of a flow diagram		Figure 1

Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and confounders	tables	Table 1 Characteristics of all ED patients and the CT users during 2010 – 2020
		(b) Indicate number of participants with missing data	4	incomplete data (n = 473)
		(c) Cohort study—Summarise follow-up time		Not applicable
Outcome data	15*	Cross-sectional study—Report numbers of outcome events or summary measures	tables	Table 2 Trends of CT use in the ED patients during 2010 – 2020
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	tables	Table 2 Trends of CT use in the ED patients during 2010 – 2020
		(b) Report category boundaries when continuous variables were categorized	tables	Table1 Characteristics of all ED patients and the CT users during 2010 – 2020
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	tables	Table 2 Trends of CT use in the ED patients during 2010 – 2020
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	figures	Figure 4 Subgroup analyses of age-standardized rates (ASRs, per 1,000 emergency department visits) in using each type of computed tomography (CT), and average annual percent changes (AAPCs)

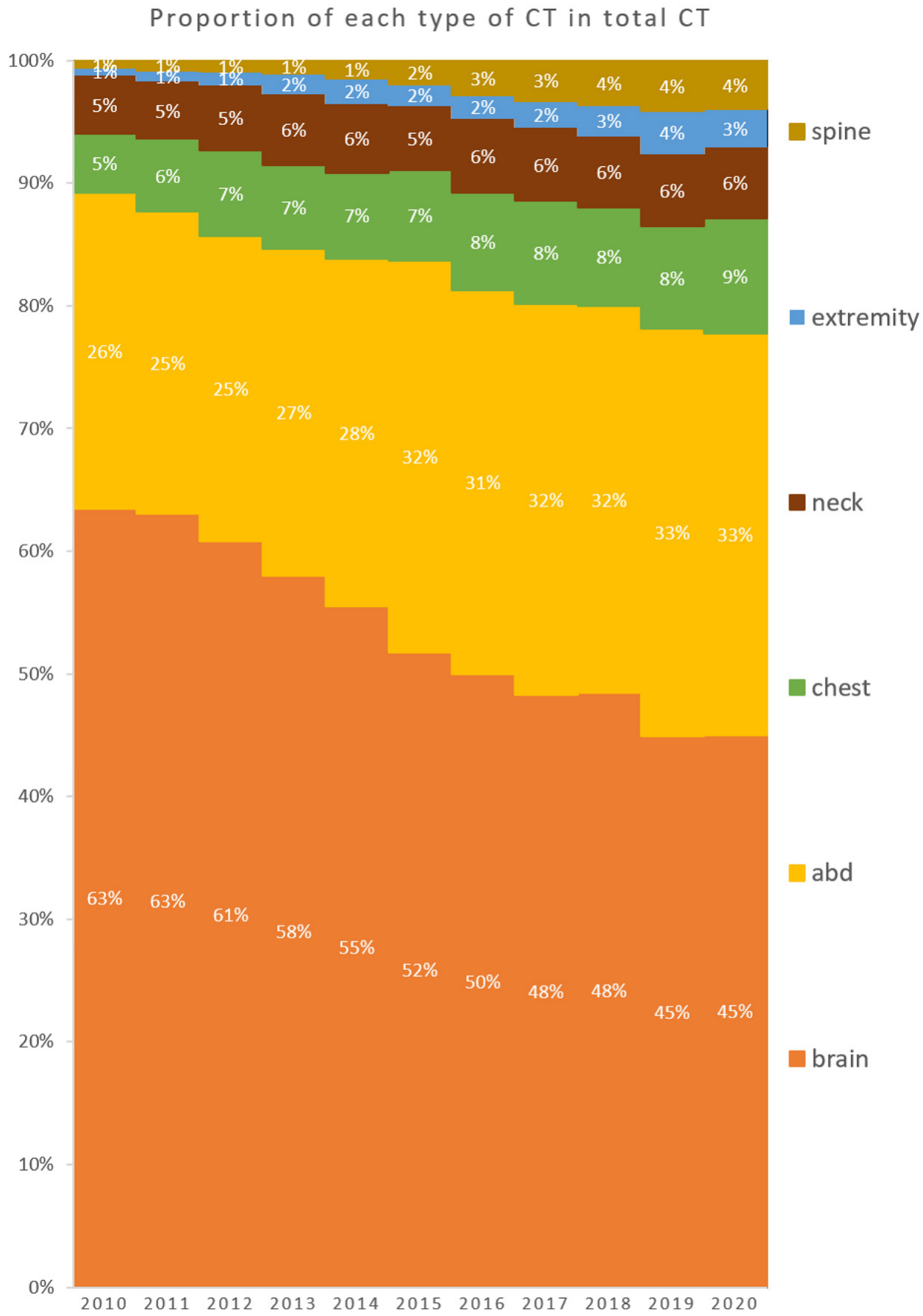
Discussion				
Key results	18	Summarise key results with reference to study objectives	8 – 9	In this study, we found that the aging effect did exist in our study population, with the mean age of ED patients increasing by five years from 2010 to 2020. Therefore, using ASR for trend analysis and comparisons has made our results less confounded by the aging effects. After age standardization, we still observed the continued growth of CT use and repeat CT imaging in Taiwan, and the increasing trends differed by CT type (Figure 1). Spine and extremity CT had the most prominent growth trends, while brain CT had the least growth trend. Furthermore, the proportion of brain CT in the total emergent CT decreased between 2010 and 2020. These findings suggest that in Taiwan, the use of brain CT in the ED setting may reach a stable status, rather than continue to grow. In addition, this study showed a stable trend of CT use in non-urgent and pediatric patients.
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	11	The findings of this study should be interpreted cautiously due to the limited external generalizability from single-center data. To address this limitation, age standardization was applied using the age distribution of Taiwan's general population, which yielded consistent results. The risk of measurement bias was low in this study because of the scrutiny of reimbursement claims by Taiwan's Bureau of NHI and the hospital. Despite our efforts to reduce the aging effects and framing bias by using ASR and AAPC, there may be residual confounding factors, such as the unmeasured health status of the study population or physician preference for CT use, that could affect our results. Finally, evaluating clinical outcomes and the appropriateness of CT use was beyond the scope of this study.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11	In conclusion, increasing trends of CT use and repeat CT imaging were found in a tertiary ED in Taiwan during 2010 – 2020, even after age standardization with the general population. Marked growth of spine and extremity CT use were also observed.
Generalisability	21	Discuss the generalisability (external validity) of the study results	11	The findings of this study should be interpreted cautiously due to the limited external generalizability from single-center data. To address this limitation, age standardization was applied using the age distribution of Taiwan's general population, which yielded consistent 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	12	This work was supported by the Center for Healthcare Database Research, E-Da Hospital [grant number EDAD1904]. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

eTable 2. Trends of any CT use in the ED patients (presenting in annual ASR per 1,000 ED visit) during 2010 – 2020, with age, sex, triage, and trauma stratification.

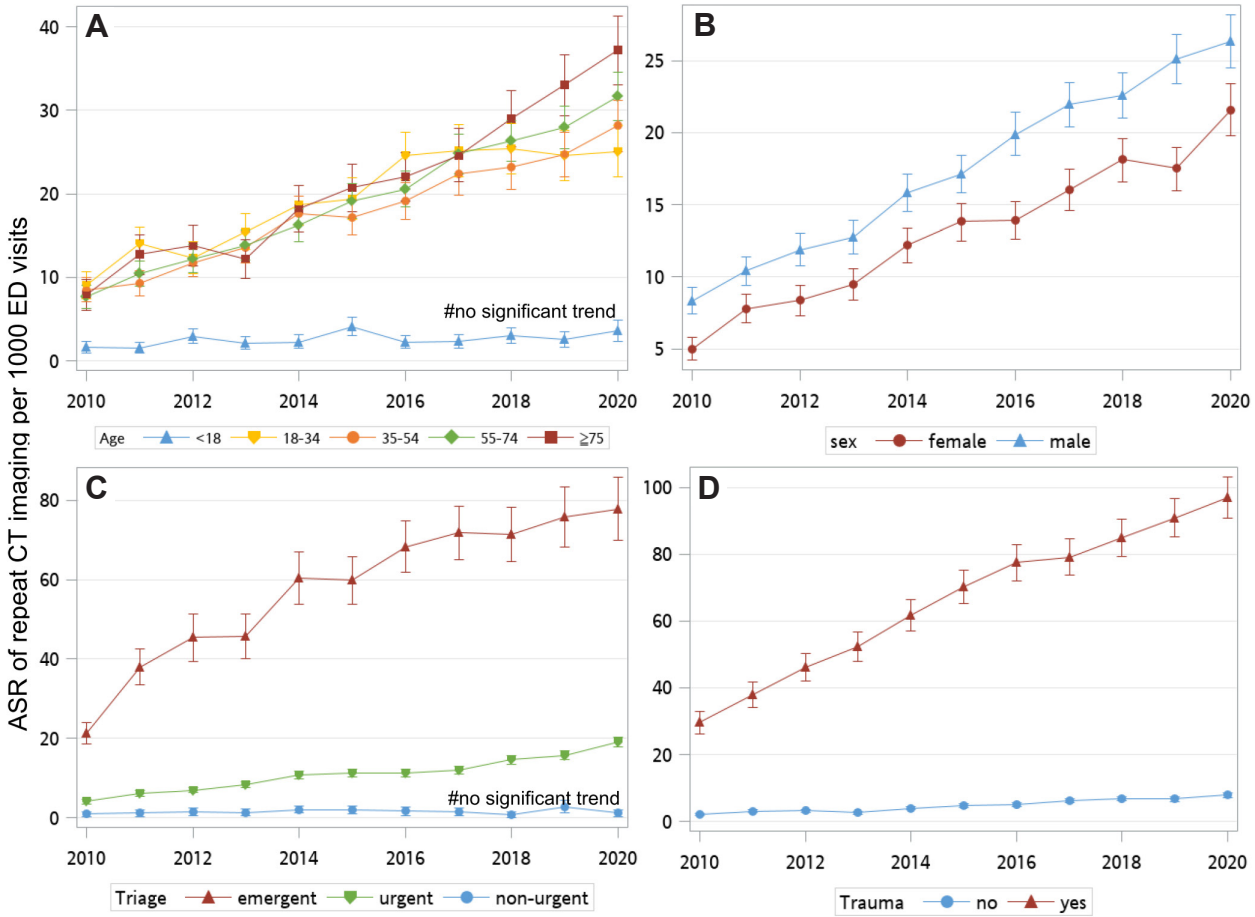
Strata	Rate 2010	95% CI	Rate 2020	95% CI	Rate difference from 2010	Growth % from 2010	AAPC	95% CI
Age								
< 18	23.4	(21.2 – 25.6)	30.2	(26.6 – 33.7)	6.8	29%	0.2	(-1.9, 2.2)[#]
18 – 34	91.6	(86.5 – 96.8)	139.5	(132.3 – 146.6)	47.9	52%	3.4	(2.5, 4.2)
35 – 54	136.4	(130.8 – 142)	227.3	(218.7 – 235.9)	90.9	67%	4.8	(4.1, 5.5)
55 – 74	172.5	(166 – 178.9)	279.6	(271 – 288.1)	107.1	62%	4	(3.3, 4.8)
≥ 75	200	(190.4 – 209.5)	311.9	(300 – 323.8)	111.9	56%	3.4	(2.7, 4.2)
Sex								
Male	120.9	(117.5 – 124.4)	192.7	(187.8 – 197.6)	71.8	59%	4	(3.5, 4.6)
Female	113.2	(109.4 – 116.9)	183.9	(178.8 – 189.1)	70.7	63%	3.8	(3.2, 4.4)
Trauma								
Yes	210.5	(202.1 – 218.9)	296.8	(286 – 307.5)	86.3	41%	3	(2.5, 3.5)
No	99.1	(96.6 – 101.7)	163.9	(160.3 – 167.5)	64.8	65%	4.4	(3.9, 5)
Triage								
Emergent	216.7	(209 – 224.3)	324.3	(311.6 – 336.9)	107.6	50%	2.8	(1.9, 3.7)
Urgent	102.7	(99.7 – 105.6)	183.5	(179.4 – 187.6)	80.8	79%	4.2	(2.9, 5.7)
Nonurgent	42.3	(38.3 – 46.4)	37.8	(32.8 – 42.8)	-4.5	-11%	-1.9	(-4, 0.2)[#]

[#] No significant trend (AAPC with 95% CI containing zero)

AAPC: average annual percentage changes; ASR: age-standardized rate; CI: confidence interval; CT: computed tomography; ED: emergency department.



eFig. 1 The proportion of each type of CT in all CT studies, 2010 – 2020.



eFig. 2 Trends of age-standardized rate (ASR) in repeat CT imaging per 1,000 ED visits, stratified by (A) age, (B) sex, (C) triage and (D) trauma. Increasing trends of ASR were observed in most subgroups, except for the subgroups of aged < 18 years and non-urgent ([#] No significant trend – AAPC with 95% CI containing zero).