Research Article

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Benefits of computed tomography in reducing mortality in emergency medicine

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Abstract: Performing accurate diagnosis using computed tomography (CT) in emergency medicine may reduce mortality rates in various diseases. In this observational, correlational and cross-sectional study, we conducted multiple regression analyses to investigate the relationship between CT utilization rates and mortality. In addition, we estimated the annual net profits from CT to show the profitability of introducing a CT system in each Japanese prefecture.

We conducted a multiple regression analysis to investigate correlations between CT utilization rates and mortality from each disease adjusted for the population density, number of doctors, as well as transportation time to the medical institution.

The results of multiple regression analysis showed that traffic accident mortality was related to CT utilization rate and population density. Extrinsic death such as mortality due to falling, drowning and asphyxia was related to CT utilization, indicating that CT in emergency medicine reduced mortality. Moreover, the annual net profit from multi-slice CT (MSCT) was estimated as positive.

Our study clearly demonstrates that CT utilization rates relate to a reduction in mortality from accidents, indicating that screening patients with CT in the emergency room has a beneficial effect and reduces mortality. Therefore, CT equipment has a beneficial effect in both emergency medicine and hospital management.

Keywords: Computed tomography; Mortality; Emergency medicine; Traffic accident; Hospital management

1 Introduction

As computed tomography (CT) systems have high spatial resolution, they are particularly useful in the diagnosis of stroke, damage to internal organs including the intracranial cavity, acute abdominal pain, as well as for cancer screening [1–5]. In recent years, use of multi-slice CT (MSCT) equipped with a multi-row detector has become widespread, and it is now possible to acquire thin slices in a short time. This has allowed inspection of the coronary arteries, colon, etc. with CT [6–9]. Moreover, with the development of iterative reconstruction method, it is now possible to obtain high-quality images with a low radiation dose [10]. Consequently, screening for lung cancer at a low dose is widely performed [11]. Due to these rapid advances and their extensive diagnostic capabilities, CT systems have quickly become widespread worldwide, especially in Japan.

In Japan, the age-adjusted mortality rate for cerebrovascular disease has dramatically reduced since 1970, and that of cancer has reduced since 2000. Mortality rates following accidents by age group have also been decreasing since 1995, with mortality from traffic accidents halving in most age groups. Both improved vehicle safety and progress in medical care may have contributed to such improvements [12]. Furthermore, development of emergency medical system including emergency transportation and treatment based on accurate diagnosis using CT systems may affect improvements in mortality associated with various diseases/injuries such as trauma, cancer and cerebrovascular events.

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Japan has the highest number of CT systems in clinical use worldwide. CT systems have been introduced not only at major hospitals, but also at small hospitals and clinics across the country. Health data obtained from the Organization for Economic Co-operation and Development (OECD) in 2013 demonstrated that the number of CT scans per million individuals in Japan was 101.3, which is about 4.3 times higher than the OECD average of 23.6 [13]. However, this could be a major liability for hospital management because CT systems are expensive [14].

Thus, in this study, we analyzed the relationship between CT utilization and reduced mortality rates of various diseases/injuries from the viewpoint of emergency medicine. Additionally, we estimated the net yearly profits from CT use by prefecture (local governments of 47 prefectures that are considered the largest administrative districts in Japan) and discussed the profitability of introducing CT systems.

2 Methods

This was an observational, correlational and cross-sectional study spanning from 2010 to 2014. We obtained data published by the Ministry of Health, Labor and Welfare of the Japanese government as described later. The data used in this study did not include detailed personal information since it was aggregated data publicized by the Japanese Government (Ministry of Health, Labor, and Welfare of Japan).

Age-adjusted mortality rates for various diseases were calculated from the 2010 Vital Statistics [15] using the annual report of aggregated data including mortality per 100,000 people. We defined age-adjusted mortality for five major causes of death in Japan: malignant neoplasms, cerebrovascular diseases, heart diseases, pneumonia, and accidents. Accidents were subdivided into traffic accidents, falling, drowning, and asphyxia. Population density data was obtained from the 2010 Population Census [16]. The number of doctors per 100,000 individuals was calculated using data from the 2011 Survey of Medical Institutions [17]. The data of transport time to the medical institution by EMS (emergency medical service) was obtained from the 2010 Current state of emergency rescue [18].

The CT utilization rate was defined as the number of examinations per CT scanner and calculated from the total number of CT units and total number of examinations in each prefecture according to the 2014 Survey of Medical Institutions [19]. The number of CT scanners in Japan was determined from the Data Book of Medical Devices & Systems 2016 (reported in 2014) [20]. Personnel expenses were calculated using the Osaka Prefectural Public Hospital Questionnaire and the 2014 Basic Survey on Wage Structure [21]. Annual CT costs were calculated as the sum of the depreciation expenses of the main unit, maintenance fees, and labor costs. This was estimated for each procedure and prefecture using a CT cost model (as shown in Table 1) and the number of CT scanners. The depreciation expenses of the main unit were calculated using a linear method on the main unit price assuming an amortization period of 6 years. The maintenance fee was calculated as the total maintenance costs each year, including periodic inspections, and all repair costs. The labor cost was estimated based on the average number of doctors, medical radiology technicians, and nurses necessary for CT examinations at Osaka prefectural public hospitals and the average number of examinations and CT systems in each prefecture.

To estimate the yearly net profits from CT by 47 prefectures, the annual net profits per CT scanner were calculated for each procedure and each prefecture using the

| Performance          | Unit price  | Depreciation | Maintenance cost | Total cost |
|----------------------|-------------|--------------|-----------------|------------|
|                      | (JPY) | (USD) | (JPY) | (USD) | (JPY) | (USD) |
| SSCT                 | 20,000,000 | 188,929 | 3,333,333 | 31,488 | 3,000,000 | 28,339 | 6,333,333 | 59,827 |
| <4 detector rows     | 30,000,000 | 283,393 | 5,000,000 | 47,232 | 7,000,000 | 66,125 | 12,000,000 | 113,357 |
| MSCT                 | 40,000,000 | 377,858 | 6,666,667 | 62,976 | 8,000,000 | 75,572 | 14,666,667 | 138,548 |
| 4–16 detector rows   | 70,000,000 | 661,251 | 11,666,667 | 110,208 | 15,000,000 | 141,697 | 26,666,667 | 251,905 |
| >64 detector rows    | 150,000,000 | 1,416,966 | 25,000,000 | 236,161 | 20,000,000 | 188,929 | 45,000,000 | 425,090 |

SSCT: single-slice computed tomography, MSCT: multi-slice computed tomography, 1(USD) = 105.86(JPY)
annual income and costs per CT scanner. The number of examinations conducted per CT scanner in each prefecture was calculated using the following equation: total number of CT examinations performed divided by total number of CT scanners in clinical use. The income per CT examination was estimated using medical treatment fees in Japan from 2014. The medical treatment fee is the remuneration that medical institutions and pharmacies receive from insurers as compensation for insured medical services. The fees corresponding to each item were added for each medical procedure conducted, and the total fee was calculated. Based on these figures, the annual income per CT scanner was calculated for each procedure and prefecture by multiplying the number of examinations per CT scanner by the income per CT examination. The income per CT examination was calculated for each procedure according to the imaging fee, contrast-enhancement fee, diagnosis fee, electronic image management, and radiologic diagnosis fee I or II (as shown in Table 2).

To analyze the relationship between CT utilization and reduced mortality rates of various diseases/injuries, we conducted the following analyses. Pearson correlation coefficients were calculated for the correlation analysis between CT utilization rates and mortality from various diseases/injuries. A multiple regression analysis was used to determine the significance of difference between the CT utilization rate and the highest correlated mortality rate. Explanatory variables included CT utilization rates for each prefecture, population density, number of doctors per 100,000 individuals, and transport time to the medical institution from the viewpoint of medical services and social infrastructure for each prefecture. A p-value <0.05 was considered statistically significant. Data processing and statistical analyses were performed using the Statistical Package for the Social Sciences version 20.0 (SPSS Japan Inc., Tokyo, Japan).

3 Results

3.1 The relationship between CT utilization rate and mortality

Table 3 shows the results of correlation analysis on the relationship between CT utilization rate and mortality from each disease. A negative correlation was observed between the CT utilization rate and age-adjusted mortality from accidents ($r = -0.598, p=0.000$). In contrast, there was no significant correlation between the CT utilization rate and mortality from malignant neoplasms, cerebrovascular disease, heart diseases, or pneumonia.

Table 4 shows the results of multiple regression analysis on mortality from accidents, which most strongly correlated with CT utilization.

Results of multiple regression analyses in which mortality was used as the dependent variable and the items in this table were used as explanatory variables.

Table 3: The relationship between CT utilization rate and mortality from each disease

| Disease                     | r   | P-value |
|-----------------------------|-----|---------|
| Malignant neoplasms         | -0.009 | 0.955   |
| Cerebrovascular diseases    | -0.370 | 0.809   |
| Heart diseases              | -0.037 | 0.809   |
| Pneumonia                   | -0.275 | 0.065   |
| Accidents                   | -0.598 | 0.000   |

CT: computed tomography

Table 2: Medical fees

| Medical fee                  | (JPY) | (USD)  |
|------------------------------|-------|--------|
| Imaging fee                  |       |        |
| <4 detector rows (including SSCT) | 6,000 | 56.7   |
| 4–16 detector rows           | 7,700 | 72.7   |
| 16–64 detector rows          | 9,000 | 85.0   |
| <64 detector rows            | 10,000| 94.5   |
| Contrast-enhanced fee        | 5,000 | 47.2   |
| Diagnostic fee               | 4,500 | 42.5   |
| Electronic imaging management| 1,200 | 11.3   |
| Radiological diagnosis fee I | 700   | 6.6    |
| Radiological diagnosis fee II| 1,800 | 17.0   |

SSCT: single-slice computed tomography, 1(USD)=$105.86(JPY)
Table 4: Relationship between mortality from accidents and CT utilization

| Variable                                      | Coefficient | Standard error | Standardized coefficient | P-value |
|-----------------------------------------------|-------------|----------------|--------------------------|---------|
| Computed tomography utilization rate          | -0.003      | 0.001          | -0.579                   | 0.000   |
| Population density                           | 0.000       | 0.000          | 0.078                    | 0.603   |
| Number of doctors                             | -0.016      | 0.009          | -0.227                   | 0.095   |
| Transport time to the medical institution     | -0.170      | 0.107          | -0.214                   | 0.122   |

Adjusted R²: 0.390

Table 5: Results of multiple regression analysis for accidents by each classification

| Type of accident | Variable                  | Coefficient | Standard error | Standardized coefficient | P-value |
|------------------|---------------------------|-------------|----------------|--------------------------|---------|
| Traffic accidents| CT utilization rate       | -0.001      | 0.000          | -0.414                   | 0.004   |
|                  | Population density        | 0.000       | 0.000          | -0.297                   | 0.045   |
|                  | Number of doctors         | -0.003      | 0.003          | -0.128                   | 0.326   |
|                  | Transport time to the medical institution | -0.069 | 0.040 | -0.227 | 0.090 |
| Adjusted R²:     |                           | 0.432       |                |                          |         |
| Falling          | CT utilization rate       | 0.000       | 0.000          | -0.363                   | 0.044   |
|                  | Population density        | 0.000       | 0.000          | 0.187                    | 0.321   |
|                  | Number of doctors         | -0.001      | 0.002          | -0.087                   | 0.605   |
|                  | Transport time to the medical institution | -0.042 | 0.028 | -0.255 | 0.139 |
| Adjusted R²:     |                           | 0.052       |                |                          |         |
| Drowning         | CT utilization rate       | -0.001      | 0.000          | -0.418                   | 0.018   |
|                  | Population density        | 0.000       | 0.000          | 0.127                    | 0.486   |
|                  | Number of doctors         | -0.003      | 0.004          | -0.125                   | 0.443   |
|                  | Transport time to the medical institution | -0.073 | 0.047 | -0.254 | 0.130 |
| Adjusted R²:     |                           | 0.102       |                |                          |         |
| Asphyxia         | CT utilization rate       | 0.000       | 0.000          | -0.323                   | 0.047   |
|                  | Population density        | 0.000       | 0.000          | -0.217                   | 0.203   |
|                  | Number of doctors         | -0.003      | 0.002          | -0.214                   | 0.162   |
|                  | Transport time to the medical institution | -0.030 | 0.026 | -0.177 | 0.252 |

Adjusted R²: 0.225

Table 5 shows the results of multiple regression analysis by classification of accidents. Mortality from traffic accidents was significantly related to the CT utilization rate and population density. Mortality from falling and drowning also related to the CT utilization rate as did mortality from asphyxia.

Results of multiple regression analyses in which mortality was used as the dependent variable and the items in this table for each classification (type of accidents) were used as explanatory variables. CT: computed tomography.

3.2 Estimation of net profits from CT by prefecture

Table 6 shows annual net profits from CT in 47 prefectures. Estimations for the annual revenue per CT scanner by prefectures varied from $33,247–$94,930 and $304,684–$632,971 for single-slice CT (SSCT) and MSCT, respectively. Meanwhile, estimations for the annual cost per CT scanner by prefectures varied from $65,668–$74,884 and $264,970–$356,700 for SSCT and MSCT, respectively. Estimations for annual net profits per SSCT scanner varied by
Table 6: Annual net profits from CT in 47 prefectures

| Prefecture | Number of CT units | Annual income (USD) | Annual cost (USD) | Annual net profits (USD) |
|------------|--------------------|---------------------|------------------|--------------------------|
|            | SSCT | MSCT | SSCT | MSCT | SSCT | MSCT | SSCT | MSCT |
| Hokkaido   | 231  | 673  | 62,326 | 425,089 | 72,258 | 312,510 | -9,932 | 112,578 |
| Aomori     | 71   | 147  | 51,072 | 358,374 | 67,817 | 293,667 | -16,745 | 64,707  |
| Iwate      | 66   | 132  | 49,478 | 371,320 | 69,127 | 279,121 | -19,648 | 92,199  |
| Miyagi     | 53   | 77   | 54,603 | 430,981 | 69,394 | 334,860 | -14,791 | 96,121  |
| Akita      | 28   | 195  | 41,106 | 479,493 | 72,728 | 317,451 | -31,622 | 162,042 |
| Yamagata   | 27   | 91   | 51,901 | 491,271 | 74,884 | 326,256 | -22,983 | 165,015 |
| Fukushima  | 62   | 174  | 91,195 | 446,602 | 73,599 | 303,382 | 17,596  | 143,220 |
| Ibaraki    | 83   | 258  | 40,634 | 462,959 | 67,441 | 310,578 | -26,807 | 152,381 |
| Tochigi    | 54   | 168  | 59,249 | 472,104 | 67,256 | 303,509 | -8,008  | 168,595 |
| Gunma      | 49   | 188  | 52,377 | 398,989 | 67,349 | 307,802 | -14,972 | 91,187  |
| Saitama    | 135  | 479  | 61,570 | 473,488 | 72,442 | 326,256 | -19,648 | 92,199  |
| Chiba      | 83   | 444  | 60,894 | 579,704 | 69,977 | 341,375 | -9,082  | 238,329 |
| Tokyo      | 219  | 1010 | 83,450 | 571,109 | 71,306 | 334,699 | 12,144  | 236,411 |
| Kanagawa   | 139  | 535  | 75,962 | 632,971 | 72,811 | 340,942 | 3,151   | 292,029 |
| Niigata    | 73   | 184  | 47,085 | 469,375 | 69,363 | 318,687 | -22,278 | 150,687 |
| Toyama     | 56   | 95   | 33,487 | 547,545 | 66,168 | 345,706 | -32,681 | 201,839 |
| Ishikawa   | 41   | 113  | 52,497 | 553,806 | 69,100 | 322,580 | -16,604 | 231,226 |
| Fukui      | 25   | 91   | 36,907 | 426,647 | 68,300 | 287,501 | -31,393 | 139,145 |
| Yamanashi  | 24   | 72   | 94,930 | 408,582 | 74,069 | 308,500 | 20,862  | 100,082 |
| Nagano     | 45   | 207  | 43,562 | 498,254 | 72,284 | 309,310 | -8,722  | 188,944 |
| Gifu       | 94   | 172  | 52,897 | 574,335 | 67,522 | 327,718 | -14,625 | 246,617 |
| Shizuoka   | 110  | 288  | 63,110 | 560,570 | 68,146 | 314,169 | -5,036  | 246,401 |
| Aichi      | 175  | 516  | 50,430 | 624,427 | 69,622 | 348,924 | -19,193 | 275,503 |
| Mie        | 78   | 132  | 48,245 | 566,459 | 67,797 | 354,602 | -19,553 | 211,857 |
| Shiga      | 18   | 91   | 61,756 | 631,964 | 70,263 | 356,700 | -8,507  | 275,264 |
| Kyoto      | 37   | 215  | 49,448 | 608,749 | 71,106 | 351,839 | -21,657 | 256,910 |
| Osaka      | 198  | 778  | 67,561 | 548,792 | 71,393 | 323,741 | -3,832  | 225,051 |
| Hyogo      | 138  | 497  | 59,410 | 496,000 | 70,330 | 324,500 | -10,920 | 171,500 |
| Nara       | 26   | 118  | 33,247 | 555,202 | 68,303 | 344,535 | -35,056 | 210,668 |
| Wakayama   | 40   | 126  | 46,330 | 408,857 | 67,493 | 301,656 | -21,163 | 107,201 |
| Tottori    | 19   | 66   | 47,401 | 460,244 | 68,454 | 316,173 | -21,052 | 144,071 |
| Shimane    | 16   | 74   | 90,830 | 439,091 | 70,382 | 316,429 | 20,448  | 122,662 |
| Okayama    | 59   | 233  | 53,053 | 426,122 | 68,384 | 299,817 | -15,331 | 126,935 |
| Hiroshima  | 80   | 322  | 58,218 | 386,224 | 68,889 | 295,934 | -10,671 | 90,290  |
| Yamaguchi  | 72   | 171  | 53,009 | 391,834 | 68,152 | 294,947 | -15,143 | 97,338  |
| Tokushima  | 62   | 116  | 42,055 | 324,197 | 65,668 | 264,970 | -23,613 | 59,227  |
| Kagawa     | 43   | 135  | 33,504 | 398,050 | 68,427 | 315,366 | -34,923 | 82,683  |
| Ehime      | 68   | 161  | 45,152 | 455,159 | 67,395 | 314,613 | -22,243 | 140,546 |
| Kochi      | 54   | 110  | 36,156 | 336,973 | 66,106 | 284,914 | -29,950 | 52,058  |
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prefecture and ranged from +$20,861 to -$35,056 with an average deficit of -$14,285. In contrast, MSCT was profitable, with annual net profits ranging from $13,064–$292,029 and an average surplus of +$147,904.

4 Discussion

Our study clearly demonstrated that CT utilization rates relate to reduced age-adjusted mortality from accidents. Specifically, significant decreases in mortality from traffic accidents and drowning were observed, indicating that CT screening for patients in the emergency room had a beneficial effect on mortality, especially for patients who experienced injuries from traffic accidents and drowning. Our study also demonstrated that the average estimated net profit from MSCT was positive (in black), whereas the average estimated annual net profit from SSCT was negative (in red). Therefore, our study indicates that MSCT equipment has a beneficial effect for both reducing mortality in emergency room patients and increasing income in hospital management.

In cases of trauma such as traffic accidents, patients often present with multiple injuries to various body parts, including the head, neck, trunk, and extremities. Wagner et al. [22] reported that the survival rate of patients with multiple injuries significantly increased when whole-body CT (WBCT) was used, and therefore, recommended using WBCT as a standard diagnostic measure. Similarly, Wada et al. [23] reported that the use of WBCT in the initial screening of patients with blunt trauma requiring emergency management (surgery or transcatheter arterial embolization) improved their survival rate. Furthermore, other studies have reported the usefulness of CT scanning for the diagnosis of blunt trauma patients in emergency room [24 - 26]. Jiang et al. [26] indicated that application of WBCT not only reduces the mortality rate of major trauma patients but also the time spent in emergency room. They showed that WBCT has higher accuracy, especially in the diagnosis of solid organ injuries compared with conventional diagnostic approaches. WBCT can significantly reduce time intervals between patient’s arrival and the end of life saving procedures, the end of diagnostic procedures, and the beginning of emergency surgery.

Generally, a delay in proper surgical care is associated with higher risk of preventable death in trauma care. Tsutsumi et al. [24] reported that WBCT can be beneficial in patients with blunt trauma that has compromised vital signs. They suggested that physicians should consider WBCT for blunt trauma patients when warranted by vital signs. Kinoshita et al. [25] reported that immediate CT diagnosis and rapid bleeding control without patient transfer, as achieved in the hybrid emergency room using an interventional radiology (IVR)-CT system, may improve mortality in severe trauma cases. Moreover, head injuries due to traffic accidents may cause intracranial hemorrhage such as acute subdural hematoma [27]. Imaging of arterial injuries causing cerebral hemorrhage has become possible by performing CT angiography [28]. Recently, the use of MSCT has become more common in the clinical diagnoses of patients and can even be used to diagnose patients who cannot hold their breath, as well as patients who make slight movements during imaging because image acquisition is very fast. Moreover, because CT scan can instantaneously acquire a wide range of images, it is useful for whole-body screening examinations and is considered effective for the initial and subsequent diagnoses of accidents. Therefore, the results of the current study showing a relationship between CT utilization rate and mortality from accidents are consistent with those from previous studies [22–28].

Table 6 continued: Annual net profits from CT in 47 prefectures

| Prefecture | SSCT | MSCT |
|------------|------|------|
| Fukuoka    | 174  | 505  | 56,303 | 445,921 | 70,698 | 321,948 | -14,396 | 123,973 |
| Saga       | 35   | 109  | 87,408 | 313,153 | 67,436 | 285,139 | 19,972  | 28,014  |
| Nagasaki   | 73   | 168  | 66,044 | 449,811 | 71,061 | 318,133 | -5,018  | 131,678 |
| Kumamoto   | 88   | 235  | 46,323 | 328,697 | 67,216 | 280,747 | -20,893 | 47,950  |
| Oita       | 45   | 181  | 42,127 | 353,114 | 66,858 | 293,316 | -24,731 | 59,797  |
| Miyazaki   | 60   | 130  | 54,662 | 325,586 | 70,151 | 298,661 | -15,489 | 26,925  |
| Kagoshima  | 103  | 253  | 54,650 | 304,684 | 69,874 | 291,619 | -15,224 | 13,064  |
| Okinawa    | 35   | 114  | 45,751 | 522,334 | 65,947 | 335,711 | -20,195 | 186,622 |
| Mean       | 76   | 241  | 55,093 | 462,451 | 69,378 | 314,547 | -14,285 | 147,904 |

CT: computed tomography, SSCT: single-slice computed tomography, MSCT: multi-slice computed tomography. 1(USD)=105.86(JPY)
Our study also indicated the interesting aspect of CT for hospital management. MSCT, which is currently being widely introduced to medical centers across Japan, appears to be highly profitable, whereas SSCT may lead hospital management into financial losses. Although annual net profits from SSCT were generally negative in our study, 3,564 SSCT scanners were still in operation for clinical diagnosis in Japan in 2014. Since SSCT scanners are not currently available commercially, they will be replaced by MSCT in the near future. This could further improve mortality rates from accidents and generate profits in hospital management. From the viewpoint of emergency medicine and hospital management, we recommend hospital managers to consider replacing SSCT scanners with MSCT. As described, our results suggest that CT is effective in reducing the mortality rate from accidents in emergency medical care while increasing profitable merit for hospital management, especially with MSCT.

Our study has several limitations to be acknowledged. First, it was impossible to obtain details on the causes of death such as traffic accidents and falling with respect to age-adjusted mortality, since the data used in our study was aggregated by the Government (Ministry of Health, Labor, and Welfare of Japan). Second, the mortality rate of each disease/injury is substantially different in each country and area [29]. The social infrastructure including emergency medical system and introduction of CT equipment are quite different even among developed countries, i.e. Japan has free access to emergency medical transportation and medical service system in the entire nation, as well as the highest number of CT systems in clinical use worldwide. Third, the data used in our study (the number of examinations per CT scanner in Survey of Medical Institutions) included both selective CT and WBCT. Therefore, we could not conduct further investigation to assess whether what type of CT scan was more effective for diagnosing injuries in the emergency room. Fourth, estimation of net profits from CT accounted for only the cost of the main unit of CT scanner, along with maintenance and labor costs as expenses. However, this did not consider the proceeds of the hospital as a whole, including indirect costs, etc. Finally, the CT cost model was a simplified estimate of the unit and maintenance costs of CT scanners, which may differ from actual costs. In particular, although the price of CT scanners thought believed to vary greatly depending on the medical institution and date of purchase; however, they were assumed to be equivalent across all institutions in this study.

5 Conclusion

Our results demonstrate that CT utilization rates are related to reduced age-adjusted mortality from accidents such as traffic accidents and drowning, indicating that CT screening of patients in the emergency room has the benefit of reducing mortality. Our results also demonstrate that the average estimation of annual net profits from MSCT is positive, whereas that from SSCT is negative. Therefore, our study suggests that MSCT equipment also has a beneficial effect of increasing income in hospital management.

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Conflict of interest statement: Authors state no conflict of interest.

References

[1] Riedel CH, Jensen U, Rohr A, Tietke M, Allke K, Ulmer S, et al. Assessment of thrombus in acute middle cerebral artery occlusion using thin-slice nonenhanced computed tomography reconstructions. Stroke 2010;41:1659-1664
[2] Chan DP, Abujudeh HH, Cushing GL Jr, Novelline RA. CT cystography with multiplanar reformation for suspected bladder rupture: experience in 234 cases. AJR Am J Roentgenol 2006;187:1296-1302
[3] Perry JJ, Stiell IG, Sivilotti MLA, Bullard MJ, Émond M, Symington C, et al. Sensitivity of computed tomography performed within six hours of onset of headache for diagnosis of subarachnoid haemorrhage: prospective cohort study. BMJ 2011;343:d4277
[4] Ng CS, Watson CJ, Palmer CR, See TC, Beharry NA, Housden BA, et al. Evaluation of early abdominopelvic computed tomography in patients with acute abdominal pain of unknown cause: prospective randomised study. BMJ 2002;325:1387
[5] International Early Lung Cancer Action Program Investigators, Henschke CI, Yankelevitz DF, Libby DM, Pasmantier MW,
Smith JP, et al. Survival of patients with stage I lung cancer detected on CT screening. N Engl J Med 2006;355:1763-1771

Saremi F, Krishnan S. Cardiac conduction system: anatomic landmarks relevant to interventional electrophysiologic techniques demonstrated with 64-detector CT. Radiographics 2007;27:1539-1565

Nasis A, Mottram PM, Cameron JD, Seneviratne SK. Current and evolving clinical applications of multidetector cardiac CT in assessment of structural heart disease. Radiology 2013;267:11-25

Johnson CD, Chen MH, Toledano AY, Heiken JP, Dachman A, Kuo MD, et al. Accuracy of CT colonography for detection of large adenomas and cancers. N Engl J Med 2008;359:1207-17. doi: 10.1148/radiol.13111196

Berrington de González A, Kim KP, Knudsen AB, Lansdorp-Vogelaar I, Rutter CM, Smith-Bindman R, et al. Radiation-related cancer risks from CT colonography screening: a risk-benefit analysis. AJR Am J Roentgenol 2011;196:816-23. doi: 10.2214/AJR.10.4907

Singh S, Kalra MK, Gilman MD, Hsieh J, Pien HH, Digumarthy SR, et al. Adaptive statistical iterative reconstruction technique for radiation dose reduction in chest CT: a pilot study. Radiology 2011;259:565-73. doi: 10.1148/radiol.11101450

National Lung Screening Trial Research Team, Aberle DR, Adams AM, Berg CD, Black WC, Clapp JD, et al. Reduced lung-cancer mortality with low-dose computed tomographic screening. N Engl J Med 2011;365:395-409

Desai A, Bekelis K, Zhao W, Ball PA. Increased population density of neurosurgeons associated with decreased risk of death from motor vehicle accidents in the United States. J Neurosurg 2012;117:599-603. doi: 10.3171/2012.6.JNS111281

Health at a Glance 2013: OECD Indicators. Paris: OECD Publishing, 2013: 86-87. (Accessed Dec 13, 2017, at https://www.oecd.org/els/health-systems/Health-at-a-Glance-2013.pdf)

Sistrom CL, McKay NL. Costs, charges, and revenues for hospital diagnostic imaging procedures: differences by modality and hospital characteristics. J Am Coll Radiol 2005;2:511-519

Vital Statistics. Japan: Ministry of Health, Labor, and Welfare. 2010. (Accessed Dec 13, 2017 at https://www.e-stat.go.jp/SG1/estat/GL08020101.do?_toGL08020101&_tstatCode=000001022183)

Population Census. 2010. Ministry of Internal Affairs and Communications, 2010. (Accessed Dec 15, 2017 at https://www.e-stat.go.jp/en/stat-search/files?page=1& toukei=00200521)

Survey of Medical Institutions. Japan: Ministry of Health, Labor, and Welfare, 2011. (Accessed Dec 13, 2017 at http://www.e-stat.go.jp/SG1/estat/NewList.do?tid=000001030908)

Multi-slice CT installation facility roster. Data Book of Medical Devices & Systems 2016. Emu I Shinko Kyokai 2016; 42-100

Basic Survey on Wage Structure. Japan: Ministry of Health, Labor, and Welfare, 2014. (Accessed December 13, 2017 at http://www.e-stat.go.jp/SG1/estat/List.do?bid=00001022183&cycode=0)

Huber-Wagner S, Lefering R, Quivik LM, Körner M, Kay MV, Pfeifer KJ, et al. Effect of whole-body CT during trauma resuscitation on survival: a retrospective, multicentre study. Lancet 2009;373:1455-61. doi: 10.1016/S0140-6736(09)60232-6

S. Whole-Body Computed Tomography During Initial Management and Mortality Among Adult Severe Blunt Trauma Patients: A Nationwide Cohort Study. World J Surg. 2018. doi: 10.1007/s00268-018-4732-5

Kinoshiba T, Yamakawa K, Matsuda H, Yoshikawa Y, Wada D, et al. The Survival Benefit of a Novel Trauma Workflow that Includes Immediate Whole-body Computed Tomography, Surgery, and Interventional Radiology, All in One Trauma Resuscitation Room: A Retrospective Historical Control Study. Ann Surg. 2017. doi: 10.1097/SLA.0000000000002527

Jiang L, Ma Y, Jiang S, Ye L, Zheng Z, Xu Y, Zhang M. Comparison of whole-body computed tomography vs selective radiological imaging on outcomes in major trauma patients: a meta-analysis. Scand J Trauma Resusc Emerg Med. 2014;22:54. doi: 10.1186/s13049-014-0054-2

Urban JE, Whitlow CT, Edgerton CA, Powers AK, Maldjian JA, Stitziel J. Motor vehicle crash-related subdural hematoma from real-world head impact data. J Neurotrauma 2012;29:277a-d81. doi: 10.1089/neur.2012.2373

Paiva WS, Andrade AF, Amorim RL, Bor-Seng-Shu E, Gattas G, Neville IS, et al. Computed tomography angiography for detection of middle meningeal artery lesions associated with acute epidural hematomas. Biomed Res Int 2014;2014:413916. doi: 10.1155/2014/413916

World Health Organization. Global status report on road safety 2015. WHO Library Cataloguing-in-Publication Data. 20 Avenue Appia. 1211 Geneva 27. Switzerland.2015. p. 1-340