Dose management for neurologic events in patients with cardiac devices

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Background/introduction

Implantable cardioverter and ventricular assist devices have significantly improved the quality of life and survival rate of patients with cardiac arrhythmias and cardiac insufficiency (1-2). Although these devices are crucial for cardiac function, life-threatening complications related to device itself, surgical technique and peri and postoperative management (bleeding, thromboembolic events, infection…etc) may occur (3-4). Neurological events may present as a devastating complication of cardiac devices and reduce the life-quality. The incidence of acute neurological events was reported as ranging between 14% and 47%, in patients with left ventricular assist device (LVAD) and implantable cardioverter defibrillator (ICD) (5-6). The common risk factors for acute neurological events include diabetes, hypertension, atrial fibrillation, peripheral vascular diseases and history of past acute neurological events (cerebrovascular events) given in different studies (6, 8). Ischemic complications secondary to thromboemboli is more frequently encountered than hemorrhagic complications. Evidence of acute neurological event potency after implantation of ICD and LVAD necessitates appropriate anticoagulation. Anticoagulation therapy in order to overcome ischemia risk in these patients group may provoke the hemorrhage as an opposed phenomena after ICD and LVAD implantation (8). Diagnosis, management and posttreatment follow-up of patients with acute cerebrovascular events, especially cerebral ischemia complicated with hemorrhage, need repetitive cranial computed tomography (CT) scans, since almost all ICD and LVAD equipments are not compatible with MRI. The increased utilization of cranial CT enhances radiation exposure and related cancer risk as an important public health (9).

Most studies related to dose reduction and radiation risks had focused on pediatric patients and pregnant women (10). In this multi-center study, our goal was to compare the cumulative radiation dose values between patients who underwent repetitive cranial CT imaging after LVAD or ICD implantation. We also aimed to determine the variability of CT acquisition parameters used in CT examinations after acute neurological event in order to predict a dose reduction plan within the diagnostic limits without affecting the imaging quality.
Description of activity and work performed

a. Patient data

This retrospective multi-center study was approved by our institutional review board. One hundred sixty-seven patients with ICD or LVAD implantation underwent neuroemergency CT examinations (head CT, head and neck CT angiography) between January 2014 and October 2018 were included in this study. Patients were classified into two groups towards the type of implanted cardiac devices as LVAD and ICD groups. LVAD group included 75 patients (120 male, 55 female, mean age: 54±11) and ICD group included 92 patients (46 male, 46 female, mean age: 67±12).

b. CT technique and dose analysis

The study data was obtained from three different medical centers using a preformatted data form. The contents of the preformatted data form included demographic characteristics of patients (age, sex, type of cardiac device, diagnosis on imaging findings) CT, number of repetitive CT scans and the CT acquisition parameters including scanning type (sequence or spiral scanning), kV, tube rotation time (TI), slice collimation (cSL) and CT dose products including computed tomography dose index volume (CTDvol), total dose length product (DLP). The participating blinded radiologists obtained the parameters relevant to radiation dose from the scan protocol generated by the seven different CT (2 GE Medical Systems, 4 Siemens, 1 Toshiba) systems from the three centers after each cranial CT and head and neck CT angiography. The cumulative radiation dose of patients with ICD and LVAD were compared and the variability of CT acquisition parameters were interrogated.

c. Statistical analysis

Results are expressed as counts (or proportions in %) or as minimum, median and maximum values (interquartile range [IQR]). Continuous and categorical variables were analyzed with a Wilcoxon rank sum and Mann-Whitney U test. P values less than 0.001 were considered statistically significant.

d. Results

A total of 1206 CT examinations (1152 head CT, 54 head and neck CTA) were performed in 168 patients. Mean number of CT examination per patient was 8. The mean number of
cranial CT scans in ICD and LVAD group was 2 (min:1, max:15) and 13 (min:1, max:37), respectively. 64 patients (%38.9) received one, 42 patients (%25.1) received 2-5, 11 patients (%6.5) received 5-10 and 48 patients (%28.7) received more > 10 cranial CT scans between 2014 and 2018.

The minimum, mean and maximum overall DLP (mGy) and CTDI_{vol} in ICD and LVAD groups are given in Table 1. There was a significant difference in cumulative radiation exposure between LVAD and ICD group (p<0.001).

CT acquisition parameters that influence radiation dose varied between the centers and the CT equipments in the same center.

Table 1: The overall DLP and CTDI_{vol} in a patient with LVAD and ICD.

<table>
<thead>
<tr>
<th>Type of device</th>
<th>Minimum overall DLP (mGy-cm)</th>
<th>Mean overall DLP (mGy-cm)</th>
<th>Maximum overall DLP (mGy)</th>
<th>Minimum CTDI_{vol}</th>
<th>Mean CTDI_{vol}</th>
<th>Maximum CTDI_{vol}</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVAD</td>
<td>4831</td>
<td>6847</td>
<td>20207</td>
<td>12.65</td>
<td>44.75</td>
<td>184</td>
</tr>
<tr>
<td>ICD</td>
<td>284</td>
<td>1129</td>
<td>9628</td>
<td>10.25</td>
<td>44.15</td>
<td>62.01</td>
</tr>
</tbody>
</table>

Table 2: Variability of CT acquisition parameters used in different vendors of three different centers are summarized.

<table>
<thead>
<tr>
<th>CT acquisition parameters</th>
<th>Subgroups</th>
<th>Scanning type</th>
<th>Sequences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spiral</td>
<td>Sequence</td>
</tr>
<tr>
<td>kV</td>
<td></td>
<td>110</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>31 (N)</td>
<td>503 (N)</td>
</tr>
<tr>
<td>TI (s)</td>
<td>0,5</td>
<td>1</td>
<td>1,5</td>
</tr>
<tr>
<td></td>
<td>109 (N)</td>
<td>102 (N)</td>
<td>249 (N)</td>
</tr>
</tbody>
</table>
Cranial CT examinations revealed unremarkable findings in 51 (30.50%) patients, acute ischemia in 13 (7.78%) patients, chronic ischemia in 62 (37.12%) patients, acute hemorrhage in 37 (22.15%) patients, prominent arterial stenosis in 2 (1.19%) patients and non-neurological event in 2 (1.19%) patients. Out of 85 patients presenting with an initial diagnosis of acute cerebrovascular accident, the final diagnosis was chronic ischemia in 43 (50.58%) patients, acute ischemia in 10 (11.76%) patients, parenchymal hematoma in 32 (37.64%) patients and normal findings in 10 (11.76%) patients.
Fig. 1: Figure A, B and C: The acquisition parameters of the three-core (tertiary) center based cranial CTs are given in the figures. A (A center), axial non-contrast CT image shows the acute ischemia in the left occipital lobe. Full filled acquisition parameters of the cranial CT are given in patients scan protocol. B (B center), axial non-contrast CT image shows the subarachnoid hemorrhage on the right parietal sulci. Full filled acquisition parameters of the cranial CT are given in patients scan protocol. C (C center), axial non-contrast CT image shows the acute hematoma on the left temporal lobe. Only CTDIvol and total DLP were given on patients scan protocol.

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Fig. 2: Graphic 1: Comparison between cumulative radiation exposure dose in LVAD and ICD groups.

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Conclusion and recommendations

The diagnostic accuracy and reliability of an imaging technique is important for the diagnosis of a pathologic condition such as bleeding, ischemia in a patient admitted to emergency department (ED) with acute neurological events. Cranial CT is the most frequently preferred imaging modality in EDs and the utilization of cranial CT in the neurology and EDs has rapidly increased in the last decades (3, 11-12). In our study, all the patients with ICD and LVAD who admitted to ED with neurological symptoms had one or more cranial CT scans as determined by study inclusion criteria.

Radiation dose reduction strategies are being more emphasized in recent years due to increased utility of CT with the advantages of high speed scanning and precious image quality. Avoidance of unnecessary radiation dose in CT is crucial especially in children and women in childbearing age period. However, patients undergoing to repetitive CT scans regardless of age group may be counted in risk group in terms of ionizing radiation exposure due to cumulative dose burden. In this group, minimizing the number of CT scans should be the first strategy for reduction of dose burden. If the number of repetitive CT scan can not be decreased adjustment and standardization of CT acquisition parameters under guidance of dose reduction techniques should be preferred. Our study was a multi-center based study and we had an opportunity to compare the CT acquisition parameters and dose products between different centers and CT vendors. Applied CT acquisition parameters and resultant variable dose values of the three centers were more variable than expected which denotes the importance of standardization of cumulative dose producing repetitive CT examinations.

Also, there was a significant difference in cumulative radiation exposure between LVAD and ICD group (p<0.001). The reason for this difference may be attributed to the fact that patients with LVAD are more prone to hemorrhagic complications than ICD group. Diagnosis of the parenchymal hematoma was significantly higher in patients with LVAD than the patients with ICD in our study. However, CT examinations performed due to suspicion of hemorrhagic complications do not require high kV tube potential and parenchymal hemorrhages can be detected with low kV values resulting in dose reduction. Increasing the gantry rotation speed and the slice collimation (cSL) by changing detector configuration and preferring spiral scanning technique can decrease the radiation dose without lowering the CT image quality in terms of hemorrhage assessment. Radiation exposure should always be managed in ALARA (As Low As Reasonably Achievable) principle. We can manipulate the CT acquisition parameters, in patients needed repetitive CT examinations, by ongoing communication with the ED team and other physicians. In patients with the suspicion of ischemia, high tube voltage and low slice collimation may be important due to potential demand for high contrast resolution in order to visualize especially early ischemic regions. However acute ischemic patients
(n:13-7.7% of all patients) constituted low percentage of total patients in our study. Also, MR device compatibility could be questioned with more detail in patients with ICD, and those patients' neuro CT examinations could be replaced by a diffusion weighted MR imaging. In our study, we could not have a chance to questionnaire the patients in detail for MRI compatibility.

Our study has several limitations, first, we were not able to find some of the CT acquisition parameters in the dose report of CT examinations, that limited to evaluate the effects of each parameter on CT doses. Second limitation was the absence of knowledge about the neuroimaging history of these patients in centers other than those included in this study. Third limitation was, the absence of separate evaluation of the radiation dose burden parameters in cranial CT and head&neck CT angiography.

In conclusion, neuro CT examinations are indispensable in neuroemergency settings. In patients with cardiac device acute neurologic events may necessitate repetitive CT examinations which result in cumulative dose burden. Applying radiation dose reduction techniques in this patient group can result in 'damping’ effect in patient dose.
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