Disaster Victim Identification using Orthopedic Implants in the 2011 East-Japan Earthquake and Tsunami

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On March 11, 2011, an earthquake (magnitude 9.0) devastated Japan’s east coast, and the associated tsunami resulted in social and mechanical destruction. Search for the missing people is still ongoing. Surgical implants are common in the general population. Because 3 of the authors had been practicing in Kamaishi and Tono at that time, this investigation was performed mainly in Kamaishi. Of the approximate 50,000 individuals in the study area of Kamaishi, a small city that is approximately 600 km from Tokyo by car (Fig. 1), more than 300 people annually (approximately 75% are > 60 years old) undergo an orthopedic implant operation at Iwate Prefectural Kamaishi Hospital, which is one of the two local hospitals with department of orthopedics in the Kamaishi area. Surgical implants and the industry-tracked lot numbers have been used forensically for decades to identify victims.

In the present investigation, we collected the information of unidentified human remains and ashes at mortuaries and temples to search surgical information that may have led to identification. Here, we explain our attempts to obtain medical information to positively identify unidentified human remains from the 2011 tsunami.

Materials and Methods

The institutional review board of Iwate Prefectural Tono Hospital approved the study. In all cases, forensic scientists conducted forensic examinations, and the police recorded specific characteristics of the human remains and belongings. The records of unidentified tsunami victims are disclosed on the official website of
Surgical scars and related information before cremation

The Iwate Prefectural Police disclosed 233 records of unidentified human remains at the time of the present investigation. Of these, 10 sets of human remains displayed characteristics of potential past surgical history as reported by the forensic scientists and police. We visited 6 mortuaries in Kamaishi and neighboring Otsuchi with the police between March 20 (9 days after the tsunami) and April 20 (40 days after the tsunami), 2011 to examine the presence of surgical scars and related information (Fig. 1). We investigated these unidentified human remains using visual and tactile examinations.

Non-combustible orthopedic implants found from unidentified ashes

After the cremation of 331 unidentified human remains before July 2011, non-combustible objects such as bone wires, pacemakers, and heart prostheses were found from 20 sets of human remains and collected by the police. Together with city officers, we visited the temples where these ashes were enshrined and visually identified these objects. We also referred to the list of unidentified victims disclosed by the Iwate Prefectural Police. If implants were found, their lot numbers and estimated surgical procedures were recorded to determine positive identification. In the geographic area we investigated, there were only 2 hospitals with orthopedics departments, which facilitated finding the surgical records that matched the estimated surgical procedure of the unidentified human remains.

Results

Surgical scars and related information before cremation

Of the 10 sets of 233 human remains that displayed characteristics of a possible past surgical history, a surgical implant was tactile in 1 set of unidentified human remains, while 1 other set was severely burned and part of an implant was exposed (Table 1). However, this set of human remains could not be investigated by autopsy at the mortuary because of the presiding Japanese law. Instead, the set of human remains was cremated later, and the orthopedic implant was found among the ashes. However, the implant lot number was destroyed by the cremation.

Non-combustible orthopedic implants found from unidentified ashes

Non-combustible objects were found in 20 sets of human remains from 331 unidentified human ashes. The implant types were recognized for all 8 of the objects that were identified as orthopedic implants (Table 2). The forensic scientists missed the presence of surgical scars in 5 of these 8 unidentified victims before cremation. The type and usage of implants could be recognizable in all 8 ashes. However, the lot numbers of only 2 ashes were fully legible. We estimated the surgical procedure, and combined this information with the lot number, size, and product type. After the surgical information was referred to operation records and tracking system, that led to positive identification.

Discussion

In our investigation, although forensic scientists and police had examined each unidentified disaster victim, their decisions regarding identification were not perfectly accurate. In the tsunami disaster, human remains degenerated and deteriorated over time, and missing subtle changes on the skin could not be avoided. Furthermore, the circumstances did not support the identification of remains (Iwase 2014).

In Japan, post-mortem incision and autopsy were strictly regulated by law at the time of this investigation. Therefore, even when a surgical scar or sign of an implant was observed on a set of remains, the examiners could not conduct a post-mortem incision of the remains for the purpose of identification outside of a certified hospital or institution. Shepherd et al. (2010) reported the utility of surgical scars, but this might be limited to certain situations. Furthermore, although lot numbers are printed on each orthopedic implant, these printed numbers are frequently destroyed during cremation or if the victim’s body is severely burned.

Forensic use of medical implants

The alternate use of orthopedic implants and dental records for disaster victim identification (DVI) is a well-known technique in forensic science that has been used for decades (Petju et al. 2007; Schuller-Götzburg and Suchanek 2007; Simpson et al. 2007; Wilson et al. 2011; Berketa et al. 2015). However, most orthopedic surgeons in the study region were not very familiar with the forensic use of implants.
A questionnaire about knowledge of DVI was distributed to orthopedic surgeons at regional conferences in 2014 (Iwate Knee Seminar, The 48th Annual Meeting of the Japanese Scoliosis Society in Morioka, and the annual meeting of the Iwate Prefectural Hospital Association). Questionnaires were completed by 108 of 386 orthopedic surgeons (28.0%) at the conferences, with 18.8 ± 8.9 years of practice. The forensic use of dental records was known by 97 (89.8%) orthopedic surgeons, while 21 (19.4%) surgeons knew that lot numbers and serial numbers could be used for identification of unidentified victims. Twenty-three (21.3%) surgeons knew that an autopsy and local incisions were legally inhibited at mortuaries at that time. Only 6 (5.6%) of the orthopedic surgeons knew that lot numbers printed on orthopedic implants could be destroyed by cremation.

The presence of various orthopedic implants could help estimate the surgical procedures performed, and the combination of the implant size and lot numbers could potentially provide information for positive identification.

<table>
<thead>
<tr>
<th>Case number*</th>
<th>Findings of the forensic examination before cremation</th>
<th>Findings of the visual and tactile examinations before cremation</th>
<th>Objects found after cremation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>A 19-cm long old surgical scar on the left knee</td>
<td>Surgical scar recognized, no palpable object</td>
<td>Dental implant</td>
</tr>
<tr>
<td>A-2</td>
<td>A plaster cast on the left leg</td>
<td>Plaster cast</td>
<td>No non-combustible object</td>
</tr>
<tr>
<td>B-1</td>
<td>A screw in the left foot</td>
<td>Tactile screw head</td>
<td>Intramedullary nail system for the tibia</td>
</tr>
<tr>
<td>B-2</td>
<td>An old surgical scar on the lateral side of the left femoral region</td>
<td>Surgical scar recognized, no palpable object</td>
<td>A φ4.5-mm cortical bone screw (46-mm long)</td>
</tr>
<tr>
<td>B-3</td>
<td>An old surgical scar on the lateral side of the left knee</td>
<td>No surgical scar recognized</td>
<td>No non-combustible object</td>
</tr>
<tr>
<td>D-1</td>
<td>An exposed screw-or bolt-like object</td>
<td>Exposed femoral stem; however, the serial number was burned and unreadable</td>
<td>Femoral stem</td>
</tr>
<tr>
<td>D-2</td>
<td>A 20-cm long surgical scar on the left knee</td>
<td>Surgical scar recognized, no palpable object</td>
<td>Victim identified by another method and could not be followed after cremation</td>
</tr>
<tr>
<td>E-1</td>
<td>A 5 × 0.5-cm surgical scar on the left knee</td>
<td>No surgical scar recognized</td>
<td>No non-combustible object</td>
</tr>
<tr>
<td>F-1</td>
<td>A 16-cm long surgical scar on the right femoral region</td>
<td>No surgical scar recognized</td>
<td>No non-combustible object</td>
</tr>
<tr>
<td>H-1</td>
<td>An 11-cm long surgical scar on the medial portion of the lower back</td>
<td>Surgical scar recognized, no palpable object</td>
<td>Victim identified by another method and could not be followed after cremation</td>
</tr>
</tbody>
</table>

*The letter in the case number represents the disaster site.
Furthermore, medical objects and their implantation sites could provide valuable information to estimate the past medical history of unidentified human remains. For example, bone wires might indicate a history of thoracic surgery; the exact wire location, e.g., the rib cage or sternum, could provide a more specific history of surgery, such as for mediastinal or heart disease. Makinae et al. (2013) used pacemaker programmers to noninvasively scan patient information from the pacemaker for DVI in the 2011 tsunami. The object type as well as the object location is important; because of these two reasons, a whole body X-ray before cremation is required.

The authors also noted that whole body X-ray should be used for screening in mass disasters. In cases of severe

Table 2. Investigation of non-combustible objects found after cremation of 331 sets of unidentified human remains.

<table>
<thead>
<tr>
<th>Case number*</th>
<th>Findings of the forensic examination before the cremation</th>
<th>Objects found after cremation</th>
<th>Lot numbers or information found on the non-combustible objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>A screw on the left foot</td>
<td>Intramedullary nail system for the tibia</td>
<td>The product name was recognized but had no readable numbers or letters.</td>
</tr>
<tr>
<td>B-2</td>
<td>An old surgical scar on the lateral side of the left femoral region</td>
<td>A φ4.5-mm cortical bone screw (46-mm long)</td>
<td>The product name was recognized but had no readable numbers or letters.</td>
</tr>
<tr>
<td>B-8</td>
<td>No surgical scar or surgical implant recognized by forensic examination</td>
<td>Bilateral artificial knee joints</td>
<td>The product name and size were recognized.</td>
</tr>
<tr>
<td>C-1</td>
<td>No description related to the surgical implant</td>
<td>Bipolar cup of an artificial hip joint</td>
<td>The product name and lot number were recognized.</td>
</tr>
<tr>
<td>D-1</td>
<td>An exposed screw-or bolt-like object (exposed femoral stem; however, the lot number was burned and unreadable)</td>
<td>Femoral stem</td>
<td>The product name was recognized but had no readable numbers or letters.</td>
</tr>
<tr>
<td>D-3</td>
<td>No description related to the surgical implant</td>
<td>A plate system for the radius</td>
<td>The product name was recognized but had no readable numbers or letters.</td>
</tr>
<tr>
<td>E-2</td>
<td>No description related to the surgical implant</td>
<td>Bilateral artificial hip joints</td>
<td>The product name and part of the lot number were recognized.</td>
</tr>
<tr>
<td>G-3</td>
<td>No surgical scar or surgical implant recognized by forensic examination</td>
<td>Nail system for the humerus</td>
<td>The product name and size were readable but no lot number was recognized.</td>
</tr>
</tbody>
</table>

*The letter in the case number represents the disaster site. Cases B-8 and C-1 were positively identified.
Orthopedic Implants for Disaster Victim Identification
destruction or degradation of human remains, it is difficult
to estimate the age and sex using visual appearance. In
addition to the detection of dense objects, estimation of age
and/or determination of whether the remains are human are
important. Prieto et al. (2007) reported their successful and
well-organized DVI in the Madrid terrorist attacks using
X-ray screening. Because the tsunami expanded longitudi-
nally along the coast where the towns are scattered and the
fragile traffic system connecting the local towns was heav-
ily devastated, we used a portable X-ray device that is usu-
ally available at Iwate Prefectural Tono Hospital, near Kamaishi,
for home medical care in remote areas; the difficult geo-
graphic conditions and lack of electricity did not allow the
use of large, whole-body X-ray and computed tomography
(CT) equipment despite their reported usefulness for screen-
ing human remains for medical information and estimation
of age and sex (Simpson et al. 2007; Blau et al. 2008;
Wilson et al. 2011; Brough et al. 2012). In the present
study, we also used a portable X-ray for home medical care,
namely the AeroDR (Konica Minolta, Tokyo), to detect
X-ray opaque objects and estimate the age and sex of the
remains (data not shown); an orthopedic surgeon provided
the estimated age and sex to regional police. Further foren-
sic examinations, before cremation, including autopsy,
would have been possible with whole body X-ray.
Therefore, in disaster situations, whole body radiography
should be performed before cremation to screen for medical
implants in unidentified remains, particularly because surgi-
cal scars can diminish with time and the degradation of
human remains.

Limitations
The main limitation of the present study was that the
number of unidentified human remains represents those
available at the time of the investigation and not the total
set of accumulated remains.

Conclusion
Lot numbers of implants and surgeon knowledge can
help to determine valuable information for positive identifi-
cation.

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Conflict of Interest
The authors declare no conflict of interest.

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