Introduction

The prevalence of surgical site infection (SSI) ranges up to 23% in orthopedic surgery [1,2]. The occurrence of the infection prolongs hospital stays [3], and is associated with morbidity [4] and excess medical costs [5]. The main source of infection is suggested the normal skin flora of the skin [6]. Therefore, appropriate presurgical skin antisepsis of the surgical site is essential.

A guideline has been suggested for the presurgical skin antisepsis regimen in general orthopedic surgery. Both mechanical cleansing and painting with multiple antisepsis agents are recommended as in traditional [7]. However, it is time-and cost-consuming, and excessive scrubbing the skin risks release of the bacteria harbored in the pores of the dermis [8]. Various alternatives to the traditional methods of presurgical antisepsis have recently been used, such as chlorhexi-
dine-gluconate spray, iodophor-in-alcohol paint, and market
soap scrub with alcohol paint [9,10].

To our knowledge, there have been no studies of the associa-
tion between antisepsis regimens and SSI in upper extremity
surgery. In our institute, using povidone-iodine only and using
povidone-iodine and alcohol-chlorhexidine painting with skin
scrubbing have both been attempted as skin antisepsis before
upper extremity surgery. The purposes of this study were to de-
terminate if the use of povidone-iodine only during skin prepa-
ration resulted in increased rate of SSI after upper extremity
surgery, and to detect any associated factors that increase the
infection risk.

Methods

Ethics statement: Institutional approval for this study was ob-
tained from the Institutional Review Board of Institutional Re-
view Board of Seoul National University Boramae Medical
Center (No. 20-2020-321). This study was a cross-sectional,
retrospective review of medical records. As the study did not
involve any further intervention on patients, we were given an
exemption for written consent.

1. Study sample

We enrolled patients who underwent upper extremity sur-
gery at a single institute from March 2020 and February 2021
and who were followed up postoperatively for at least 3 months.
During the period, the method of presurgical antisepsis was
decided by the preference of the chief resident between using
povidone-iodine only (“single regimen”) and using iodine-al-
cohol-chlorhexidine with skin scrubbing (“triple regimen”).
Because the surgeons did not participate in this decision, they
were not aware of how the skin had been prepared when they
started the surgery. We excluded surgeries for infection or ab-
cess of the soft tissue or bone.

Before the presurgical skin preparation, a razor was used to
remove hair from the operative site. Patients in the triple regi-
men group underwent a vigorous 5-minute scrub using ure-
thane sponges saturated with povidone-iodine detergent (avail-
able iodine, 0.75%). Detergent was then washed away with al-
coholic chlorhexidine, before painting the operative site with
aqueous povidone-iodine solution (available iodine, 1.0%),
which was allowed to air-dry. Patients in the single regimen
group underwent painting of the operative site with aqueous
povidone-iodine solution (available iodine, 1.0%) only. Single
application of aqueous povidone-iodine solution was also al-
lowed to air-dry.

Cefazolin was given as intravenous antibiotics to all patients
for prophylactic purposes. The dose differed according to the
bodyweight of the patients; –1 g for those under 70 kg and 2 g
for those over 70 kg. We administered the appropriate dose one
hour before the skin incision, and additionally if the surgery
lasted more than three hours. Because of the insurance policy,
no oral antibiotics were prescribed after the discharge that was
made 1 day after the surgery, and the patients were educated
not to check the wounds at home unless seemed contaminated.
At the follow-up visits, the routine evaluation included labora-
tory check-ups and inspection of the wound.

2. Clinical assessment for surgical site infection

The patients were evaluated as either marked elevation of
C-reactive proteins (CRP) at 2 weeks after surgery, superficial
and deep SSI. The level of CRP was regarded as markedly ele-
vated if the level exceeded 1.5 mg/dL [11]. An elevation of CRP
was considered high inflammatory status. Assessment of SSI
was made following National Healthcare Safety Network [12].
If the surgical wound had at least one sign among redness,
warmth, or focal tenderness, it was diagnosed as superficial SSI
and oral antibiotics was prescribed. If the elevated CRP level
and presence of the infection signs persisted for more than 1
month after the surgery, it was diagnosed as deep SSI, and re-
admission was made for more aggressive management such as
intravenous antibiotics therapy or surgical debridement.

3. Data collection

We collected demographic factors, such as age, sex, and body
mass index (BMI). To evaluate risk factors associated with SSI,
presence of diabetes mellitus and smoking status were identi-
fied. For surgical factors, we checked surgical time, whether an
open incision was made for the procedure or an arthroscopic
or closed reduction procedure was performed, and whether the
surgery was emergency or elective procedure. Whether metal
implants were inserted and kept inside the body was con-
firm. We also documented whether the surgical procedure
involved bony tissue or not.

4. Statistical analysis

All statistical analyses were performed using the IBM SPSS
Statistics ver. 26.0 (IBM Corp., Armonk, NY, 2006), and a
p-value of < 0.05 was considered statistically significant. We
generated descriptive statistics for all variables and assessed
distributions of continuous variables. The mean, standard devi-
ation, and percentage were calculated. The occurrence of SSI
was compared between the single regimen group and the triple
regimen group using the chi-square tests. To determine which factors are associated with the occurrence of SSI, univariate logistic regression analyses were performed for age, sex, BMI, diabetes mellitus, smoking, presurgical antisepsis regimen, and surgical factors including use of open incision, insertion of metal implant(s), and bone surgery. For variables with p-values of <0.1, we further performed multivariate logistic regression analysis.

**Results**

1. **Patient characteristics**

   Among 190 patients who were surgically treated at our hospital, 175 patients (male, 81 and female, 94) met the criteria and were included in the study. Their average age was 52.0 ± 22.0 years, and the average BMI was 24.5 ± 3.9 kg/m². Twenty-five (14.3%) had diabetes mellitus and 30 (17.1%) were current smoker. Surgery was performed most commonly for wrist (87 patients, 49.7%), elbow (39 patients, 22.3%), and hand (27 patients, 15.4%). Other upper extremities included forearm (13 patients, 7.4%), finger (six patients, 3.4%), and upper arm (three patients, 1.7%). The surgical time averaged 39.3 ± 10.7 minutes. Seventy-six among 175 procedures (43.4%) were elective surgeries. Triple regimen was used as presurgical antisepsis in 97 patients (55.4%) and single regimen in 78 patients (44.6%). Marked elevation of CRP at 2 weeks after surgery was found in 27 patients (15.4%). Use of single regimen was associated with the marked elevation with odds ratio (OR) of 2.425 (95% confidence interval [CI], 1.040–5.655) (Table 1).

2. **Surgical site infection between presurgical antisepsis regimens**

   Superficial SSI was diagnosed in six patients (3.4%), and deep SSI in three patients (1.7%). The rate of superficial and deep SSI did not differ according to the regimen selection (Table 2).

3. **Associated factors with C-reactive protein elevation and surgical site infection**

   The univariate logistic regression analysis showed that use of

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total</th>
<th>Single regimen&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Triple regimen&lt;sup&gt;b&lt;/sup&gt;</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>175</td>
<td>78</td>
<td>97</td>
<td>0.162</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>52.0 ± 22.0</td>
<td>54.6 ± 19.8</td>
<td>49.9 ± 23.5</td>
<td>0.162</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td>0.521</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>81 (46.3)</td>
<td>34 (43.6)</td>
<td>47 (48.5)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>94 (53.7)</td>
<td>44 (56.4)</td>
<td>50 (51.5)</td>
<td></td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>24.5 ± 3.9</td>
<td>24.7 ± 4.1</td>
<td>24.4 ± 3.8</td>
<td>0.642</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td></td>
<td>0.214</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>150 (85.7)</td>
<td>64 (82.1)</td>
<td>86 (88.7)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>25 (14.3)</td>
<td>14 (17.9)</td>
<td>11 (11.3)</td>
<td></td>
</tr>
<tr>
<td>Smoking status</td>
<td></td>
<td>0.911</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>144 (82.3)</td>
<td>64 (82.1)</td>
<td>80 (82.5)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>30 (17.1)</td>
<td>13 (16.7)</td>
<td>17 (17.5)</td>
<td></td>
</tr>
<tr>
<td>Preoperative CRP (mg/dL)</td>
<td>0.24 ± 0.40</td>
<td>0.22 ± 0.29</td>
<td>0.25 ± 0.47</td>
<td>0.581</td>
</tr>
<tr>
<td>Site</td>
<td></td>
<td>0.655</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finger</td>
<td>6 (3.4)</td>
<td>5 (6.4)</td>
<td>6 (6.2)</td>
<td></td>
</tr>
<tr>
<td>Hand</td>
<td>27 (15.4)</td>
<td>13 (16.7)</td>
<td>9 (9.3)</td>
<td></td>
</tr>
<tr>
<td>Wrist</td>
<td>87 (49.7)</td>
<td>47 (60.3)</td>
<td>42 (43.3)</td>
<td></td>
</tr>
<tr>
<td>Forearm</td>
<td>13 (7.4)</td>
<td>1 (1.3)</td>
<td>8 (8.2)</td>
<td></td>
</tr>
<tr>
<td>Elbow</td>
<td>39 (22.3)</td>
<td>11 (14.1)</td>
<td>28 (28.9)</td>
<td></td>
</tr>
<tr>
<td>Upper arm</td>
<td>3 (1.7)</td>
<td>1 (1.3)</td>
<td>4 (4.1)</td>
<td></td>
</tr>
<tr>
<td>Surgical time (min)</td>
<td>39.3 ± 10.7</td>
<td>39.6 ± 12.4</td>
<td>39.1 ± 9.1</td>
<td>0.809</td>
</tr>
<tr>
<td>CRP at 2 weeks, &gt; 1.5 mg/dL</td>
<td>27 (15.4)</td>
<td>17 (21.8)</td>
<td>10 (10.3)</td>
<td>0.037*</td>
</tr>
</tbody>
</table>

Values are presented as number only, mean±standard deviation, or number (%).

CRP, C-reactive protein.

<sup>a</sup>Povidone-iodine, <sup>b</sup>povidone-iodine and alcohol-chlorhexidine.

*p < 0.05, statistical significance.
Table 2. Occurrence of surgical site infection according to the presurgical antisepsis regimen

<table>
<thead>
<tr>
<th></th>
<th>Single regimen (^a) (n = 78)</th>
<th>Triple regimen (^b) (n = 97)</th>
<th>OR (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial surgical site infection</td>
<td></td>
<td></td>
<td>2.568 (0.458–14.401)</td>
<td>0.268</td>
</tr>
<tr>
<td>No</td>
<td>74 (94.9)</td>
<td>95 (97.9)</td>
<td>2.425; 95% CI, 1.040–5.655</td>
<td>0.040*</td>
</tr>
<tr>
<td>Yes</td>
<td>4 (5.1)</td>
<td>2 (2.1)</td>
<td>6.636; 95% CI, 1.259–34.969</td>
<td>0.026*</td>
</tr>
<tr>
<td>Deep surgical site infection</td>
<td></td>
<td></td>
<td>2.526 (0.225–28.389)</td>
<td>0.437</td>
</tr>
<tr>
<td>No</td>
<td>76 (97.4)</td>
<td>96 (99.0)</td>
<td>2.425; 95% CI, 1.040–5.655</td>
<td>0.040*</td>
</tr>
<tr>
<td>Yes</td>
<td>2 (2.6)</td>
<td>1 (1.0)</td>
<td>6.636; 95% CI, 1.259–34.969</td>
<td>0.026*</td>
</tr>
</tbody>
</table>

Values are presented as number (%).

OR, odds ratio; CI, confidence interval.

\(^a\)Povidone-iodine, \(^b\)povidone-iodine and alcohol-chlorhexidine.

Table 3. Regression outcomes between surgical site infection and other study variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>CRP elevation at 2 weeks</th>
<th>Oral antibiotics restarted</th>
<th>Readmission</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>p-value</td>
<td>OR (95% CI)</td>
</tr>
<tr>
<td>Age</td>
<td>1.012 (0.993–1.032)</td>
<td>0.227</td>
<td>1.033 (0.983–1.085)</td>
</tr>
<tr>
<td>Sex</td>
<td>0.916 (0.401–2.090)</td>
<td>0.835</td>
<td>0.577 (0.103–3.236)</td>
</tr>
<tr>
<td>Body mass index</td>
<td>1.011 (0.907–1.126)</td>
<td>0.843</td>
<td>1.015 (0.826–1.248)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>2.528 (0.938–6.816)</td>
<td>0.067</td>
<td>6.636 (1.259–34.969)</td>
</tr>
<tr>
<td>Smoking</td>
<td>0.585 (0.164–2.089)</td>
<td>0.409</td>
<td>0.993 (0.112–8.828)</td>
</tr>
<tr>
<td>Single regimen (^a)</td>
<td>2.425 (1.040–5.655)</td>
<td>0.040*</td>
<td>2.541 (0.453–14.252)</td>
</tr>
<tr>
<td>Surgical factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open incision</td>
<td>0.970 (0.262–3.585)</td>
<td>0.963</td>
<td>0.600 (0.066–5.426)</td>
</tr>
<tr>
<td>Metal implant</td>
<td>3.602 (1.184–10.953)</td>
<td>0.024*</td>
<td>NA</td>
</tr>
<tr>
<td>Bone surgery</td>
<td>2.130 (0.693–6.540)</td>
<td>0.187</td>
<td>NA</td>
</tr>
</tbody>
</table>

CRP, C-reactive protein; OR, odds ratio; CI, confidence interval; NA, not applicable.

\(^a\)Povidone iodine.

\(^*\)p < 0.05, statistical significance.

Our institute in a blinded fashion, for which comparison was made through this study. Regardless of other evaluated parameters, marked CRP elevation was associated with using single regimen as skin antisepsis. However, rate of superficial and deep SSI was not increased.

In the multivariate analysis model including diabetes mellitus, single regimen, and metal implant, the marked CRP elevation at 2 weeks was associated with single regimen (adjusted OR, 2.439; 95% CI, 1.022–5.822) and surgical procedure using metal implant (adjusted OR, 3.530; 95% CI, 1.139–10.944), only. In superficial and deep SSI, multivariate analysis was not performed because the number of factors with a p-value of < 0.1 was insufficient.

Discussion

Appropriate selection of presurgical skin antisepsis regimen in orthopedic surgery is important for prevention of SSI. Two different regimens were used for upper extremity surgeries at our institute in a blinded fashion, for which comparison was made through this study. Regardless of other evaluated parameters, marked CRP elevation was associated with using single regimen as skin antisepsis. However, rate of superficial and deep SSI was not increased.

Use of multiple agents for antisepsis has been the standard of care as skin antisepsis before performing general orthopedic surgery [7]. Unlike the general standard, our study suggested that, after the upper extremity surgeries, SSI did not increase even when only povidone-iodine was used. This might be explained by notably low rate of SSI in upper extremity in comparison to other body parts. The high resistance to the occurrence of SSI in upper extremity can be a reason for choosing different antisepsis regimen. Blood supply to the upper extremity is more abundant than to the lower extremity, and hygiene control is easier [13,14]. This anatomical factor may reduce the risk of SSIs. Shorter operation time is another reason for the low rate of SSI. Duration of operation is an independent risk factor for SSI [15]. Besides, despite the broadest antimicrobial spectrum, povidone-iodine has shorter duration of activity.
than chlorhexidine [16,17]. For upper extremity surgeries with short operation time, necessity for using long-acting antisepsis would have been diminished, which might have reduced the effect of alcoholic chlorhexidine in our cases.

Results of our study do not imply that the single regimen can substitute the triple regimen. Several studies support the use of multiple regimens for general orthopedic surgeries [7]. Its superior antimicrobial effect is evident, especially when alcohol-chlorhexidine is included [18]. Our study also showed that the level of CRP at 2 weeks after the surgery was higher in the single regimen group than in the triple regimen group. This means that postsurgical inflammation lasted longer and that close follow-up for the SSI is required. Small number of subjects was used for this study, and the increase in the rate of SSI may reach statistical significance in a large-population study.

Our study can serve as a reference for upper extremity surgeries performed under unfavorable conditions. Strict guidelines can sometimes limit the optimal treatment. Povidone-iodine is relatively common antisepsis that is also used for simple wound care. Therefore, it can be used in urgent situations where invasive procedure is, though, necessary. Moreover, surgical practices that adhere to strict antisepsis guideline might not be possible in developing countries because of cost and available antisepsis agents, for which regimen of using povidone-iodine only can be attempted according to results of our study.

There are several limitations in this study. First, this was not a prospective randomized study. Second, as surgical factors, we evaluated whether an open incision was used, whether metal implant was inserted, and whether the surgery involved the bony tissue. However, other factors such as length of the incision site may also affect the infection risk, which was not evaluated. Third, the local bacterial load was not calculated. Fourth, because of the insurance policy, the CRP measurement could not be made at other perioperative periods except 2 weeks after surgery, unless SSI was suspicious. This limited the evaluation of the postoperative CRP level to be made only once in most of the patients who did not experience the SSI.

Conclusion

Use of triple regimen has been the standard of care for preoperative skin antisepsis in the orthopedic field. Our study suggests that single regimen of using povidone-iodine alone could be similarly effective in preventing SSI after upper extremity surgeries.


