Antimicrobial Sutures: New Strategy in Surgical Site Infections

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This chapter reviews a new strategy in surgical site infections and an update of antimicrobial sutures for wound closure following surgery with the evidence of clinical effectiveness, safety and guidelines for the use of antibacterial sutures for preventing surgical site infections that more number of publications has been published recently. Surgical site infections (SSIs) occur when pathogenic organisms proliferate in surgical wounds, result in impede wound healing, cause separation of the wound edges (dehiscence), and increase the risk of abscess in deeper wound tissues. Serious SSIs can progress from local to systemic infection, increase mortality risk associate with longer length of stay in the hospital, and cause a greater risk of readmission and higher healthcare costs. Sutures can be a source of surgical wound contamination due to bacterial adherence and colonization. Sutures impregnated or coated with antibacterial agents have been developed in an attempt to reduce bacterial adherence and colonization of suture materials. Vicryl Plus, a suture made from polyglactin 910 (an absorbable suture material) coated with the antiseptic agent triclosan, is an example of one such antimicrobial suture product.

Keywords: Surgical site infections, Antimicrobial sutures, Antibacterial sutures, Polyglactin 910 coated with Triclosan, Vicryl Plus, Triclosan, Review, Surgical sutures

1. Introduction

Surgical site infections (SSIs) are a major source of prolonged illness, less frequently, and a cause of death in surgical patients. With an estimated 27 million surgical procedures each year in USA, and a 2–5% rate of SSIs, approximately 300,000–500,000 SSIs can be predicted to occur annually [3]. They are believed to increase the risk of dying 2–11 folds, with 77% of these deaths attributed directly to the surgical site infection [4]. At least 5% of patients undergoing surgery developed SSIs. Major complications such as deep sternal infections have serious clinical consequences, including death. The duration of the hospital stay increases 20-fold, and the cost increases 5-fold, which results in a net loss of reimbursement to the hospital. The hospitalization at present creates direct costs, which can be estimated in excess of USD 1.5 billion annually. Even there are not evaluations in emotional impact on patients and their families. It has been reported that 18% of SSIs lead to disability lasting greater than 6 months [4].

Although continuous advances in aseptic principles of surgery and the ongoing improvement of sterile surgical technique [8-10], the association between staphylococcal and surgical site infections continues developing intense. Although it is clear that coagulase positive species such as S. aureus and coagulase negative species such as S. epidermidis are common skin flora. Both species are introduced easily into incisions. The exact pathophysiology of SSIs in “clean” or “clean-contaminated” procedures are not completely understood. As the majority of all operative procedures are classified within one of these two categories, the scale of this problem is considerable. The first commercial antimicrobial suture, Polyglactin 910 suture coated with triclosan, Vicryl Plus, was approved for clinical use by the US Food and Drug Administration (US FDA) since 2002 [11]. The efficacy study in this suture was still unclear for decade until present. The efficacy of this suture was unclearly used and should be re-evaluated the efficacy of this suture that clearer than in the past.

2. Definition and Incidence of Surgical Site Infections

The term ‘surgical site infections’ was introduced in 1992 to replace the previous term ‘surgical wound infections’. SSIs are defined as infections occurring within 30 days after a surgical operation (or within one year if an implant is left in place after the procedure) and affecting either the incision or deep tissue at the operation site [12]. SSIs are classified into incisional and organ/spaces surgical site infections. Incisional SSIs are further divided into superficial incisional SSIs - involving only skin and subcutaneous tissue and deep incisional SSIs - those involving deeper soft tissues of the incision. Organ/spaces SSIs involves any part of the anatomy (i.e. organ or space) other than incised body wall layers that was opened or manipulated during an operation [4]. According to the National Nosocomial Infections Surveillance System, the most frequently isolated pathogens from SSI are Staphylococcus aureus (20%) and coagulase-negative staphylococci [9]. These organisms are acquired from the exogenous environment or the patients’ own flora and hence are introduced easily into wounds [13].

To reduce the risk of surgical site infections, effective and persistent skin antisepsis, meticulous operative technique, appropriate antimicrobial prophylaxis, and identification of strategies for decreasing wound contamination must be used; patient-related factors such as age, gender, body mass index, underlying disease, co-morbidities, prior operative
procedures, and life-style factors such as smoking and alcohol drinking habits must be highlighted [16]. Within the past 10 years, surgeons have embraced adjunctive innovative technology to reduce the risk of healthcare-associated surgical site infections. Within the surgical arena, innovative intra-operative strategies such as continuous insulin infusion, hyperoxia, and continuous antibiotic infusion are recognized to mitigate the risk of infectious morbidity, improving patient outcomes. There have challenged the expected source of wound contamination, usually attributed to the patient or a break in surgical technique, suggesting that the surgical wound can be seeded by exogenous flora from members of the operative team. The source of this flora has been identified as nasopharyngeal (shedding), and the causal linkage is based on intra-operative air sampling and molecular studies using pulse-field gel electrophoresis [5].

Data from the United States Centers for Disease Control National Nosocomial Infections Surveillance (CDC NNIS) system shows that SSIs are the third most frequently reported nosocomial infections, accounting for 16% of such infections among hospitalized patients and 38% among surgical patients [2]. Similarly, European data suggests that the incidence of SSIs may be as high as 20% depending on the procedure, the surveillance criteria used and the quality of data collection. Patient with SSIs are more likely to require readmission to hospital or intensive care unit (ICU) treatment, and are at higher risk of death, than those without such infections. [12]. In summary, more investigations are necessary to compact this SSIs.

3. Sutures related Surgical Site Infections

The role of suture material in the development of wound infections has been the subject of speculation among surgeons since the 1960s [17, 18]. Sutures are a contributory factor in infection; in fact, 66% of SSIs are related to the incision [19]. Microbial adherence to the surface of suture material has been reported in the surgical literature for many years. The presence of foreign materials in a wound enhances the susceptibility of surrounding tissues to infection. The number of bacteria needed to establish infection can be reduced 10,000-fold by the presence of a silk suture [16]. In fact, they found that in the presence of sutures, only 100 colony-forming units (CFU)/mg are necessary to produce infection [15]. Various bacteria may contaminate not only the tissue in the surgical wound, but the actual suture material. Once suture material becomes contaminated, local mechanisms of wound decontamination become ineffective [21, 22].

Sutures, that present virtually in all major operative procedures, may create a setting in which low numbers of bacteria proliferate while sequestered from host defenses. Any suture product of natural or synthetic composition and of mono- or multi-filament construction is susceptible to bacterial attachment and colonization. It is also clear that colonization is associated with surgical site infections [13]. Sutures, like most other implants, have a non-shedding surface to which bacteria can adhere, form biofilms and potentiate SSIs. The adherence of bacteria to various sutures has been investigated, and variations in adherence-affinity correlated with infection. ‘Biofilms’ are ubiquitous and form whenever micro-organisms such as bacteria, yeasts, algae, fungi, or protozoa attach to surfaces [7]. Cristina et al [24], 1985, reports that percutaneous sutures approximating skin edges were often colonized from the body surface into the wound track by strains of *S. epidermidis* capable of producing an amorphous extracellular matrix (biofilms), protecting the microbial populations from host defense factors. Gomez-Alonso et al, 2007, show the presence of biofilms around the bacteria after 60 minutes, and this material appeared adhered to the sutures three hours after contamination [15]. Once attached, free-living bacteria undergo a phenotypic change and, within minutes, deposit ‘slime’: extracellular polymeric material (EPS) or biofilms matrix. Implants have non-shedding surfaces, which can be colonized by skin or other bacteria during surgery, to form a biofilms. At least 60% of human infections are believed to involve biofilms and the recognition that biofilms are the dominant mode of microbial growth, and that the majority of bacteria exist in biofilms, is still recent emphasized [7]. Once established, in the environment or in infections, biofilms bacteria are difficult to treat because, shielded within the matrix, they are less susceptible to antibiotics and antiseptics. This recalcitrance is not reflected by laboratory susceptibility tests and a bacterium shown to be susceptible to antibiotics may be impossible to treat in a biofilms. A reason for the reduced susceptibility of biofilm-embedded organisms, compared with free living bacteria counterparts, and includes: heterogeneity of growth rates; cells being in a stationary physiological phase, present as recalcitrant ‘persisters’ cells or able to degrade antimicrobials; and reduced rates of penetration of the biofilms by antibiotics. Biofilms can also shield their constituent micro-organisms from the body’s immune system. The free-living form of the isolate was susceptible in vitro but in biofilms was resistant. Once a biofilms infection is established on an implant, it usually needs removal and antibiotic treatment [7, 8, 14].

4. The role of Antimicrobial Sutures

The antimicrobial suture is interesting. Fowler [25], 1965, recommends that all suture materials be steeped in a 1/2,000 solution of chlorhexidine before suturing reduces surgical wound infections, although many manufacturers had argued against him. The actual development of an antibacterial surgical suture has been under consideration since early 1980s [5]. Preventative strategies include prophylactic antibiotics before the biofilms can form, or ‘intelligent’ surfaces that prevent colonization or have antimicrobial properties. Potential antiseptics for coating surfaces include chlorhexidine,
polyhexamethylene biguanide (PHMB), octenidine and triclosan. Compared with antibiotics, which generally have single pharmacological targets, which select for resistance, antiseptics have several or multiple targets and true ‘resistance’ is rare. Antimicrobial-impregnated implants, which prevent bacterial adhesion and biofilms formation, can avoid long-term, ineffective, systemic antibiotics, reduce the risk of microbial resistance generation and need for implant removal. Ideally, antiseptics should have a rapid potent and broad microbiocidal spectrum with long-lasting effects and no risk of developing antimicrobial resistance. They should be biocompatible with medical products, not impair healing processes and be well tolerated in wounds with no toxicity or systemic absorption [7]. Recently, the only substance being used for impregnation in suture is Triclosan.

Triclosan

Figure 1. The chemical structure of Triclosan.

Triclosan 5-chloro-2 (2, 4-dichlorophenoxyphenol) is a broad-spectrum antimicrobial agent developed over 40 years ago [1]. The chemical structure was shown in Figure 1. In the United States, triclosan has been used in underarm deodorants and deodorant soaps since 1960s. It was first introduced in the healthcare industry in a surgical scrub at 1% in 1972 and for oral care in toothpaste in Europe in 1985 [28]. In 1989, triclosan was approved for use in cosmetics, which can be used up to 0.3% by the European Community Cosmetic Directive [29]. Over the last 20 years, the use of triclosan has grown rapidly in personal care products including soap, hand sanitizer, cosmetics, and toothpaste, as well as household products such as odor-fighting socks and germ-resistant sponges, kitchenware, and bedding. A 2001 U.S. study found triclosan in 76% of 395 commercial soaps examined [30]. At the beginning, the mode of action was supposed to be through nonspecific disruption of the bacterial cell membrane. Newer studies, however, revealed that the target of triclosan is the Fab I gene, which blocks bacterial fatty acid synthesis (particularly the enzyme enoyl-acyl carrier protein reductase) [30]. The combined effect of triclosan with antibiotic, amoxicillin, gentamicin, nitrofurantoin and the fluoroquinolones was superior when considering significant increases in susceptibility. The synergistic effects of triclosan and several antibiotics are consistent with a triclosan-dependent metabolic strain and/or membrane disruptive effect, and offers important insight into the combined use of antimicrobial compounds in clinical practice [31].

The antimicrobial spectrum and speed of activity of triclosan are well documented both as an active ingredient and in a wide array of formulations [28]. A comprehensive submission of published, unpublished, and historical data was prepared for the FDA and includes in vitro and in vivo data on triclosan. These references include more than 1000 in vitro tests performed with triclosan formulations on a broad array of microorganisms such as fungi, Clostridium difficile, methicillin-resistant Staphylococcus aureus (MRSA), and vancomycin-resistant Enterococcus. The results indicate the formulations have similar broad-spectrum antiviral activity on adenovirus 2, herpes simplex virus, type 1, HIV-1, influenza A, and rhinovirus 37 at both concentrations with a high level of activity on enveloped viruses such as herpes simplex virus, HIV-1, and influenza [28].

5. Clinical Study of Antimicrobial Sutures

5.1 In Vitro Study

The susceptibility of the most common device-related pathogens combined with inherently low toxicity makes triclosan a favorable candidate for use in the clinical setting as an antimicrobial suture. Many investigators have examined the relationship of suture construction and chemical composition as it relates to bacterial attachment and surgical infection. For example, Rothenburger et al [13], 2002, report ability of coated polyglactin 910 sutures with triclosan to inhibit the growth of wild-type and methicillin-resistant Staphylococcus aureus and S. epidermidis using several in vitro models. From these investigations, it is explicit that any suture product of natural or synthetic composition and of mono or multi-filament construction is susceptible to bacterial attachment and colonization. Explicitly, colonization is associated with surgical site infection. These data clearly support the conclusion that coated polyglactin 910 suture with triclosan provides an antimicrobial effect sufficient to prevent in vitro colonization of the suture by S. aureus included MRSA and S. epidermidis by using several in vitro models. For evaluated the effect of biofilms, Edmiston et al [32], 2004, found the adherence of nosocomial surgical pathogens like MRSA, glycocalyx-producing S. epidermidis, VRE, E. coli,
and *Pseudomonas aeruginosa* that produce biofilms that can prevent microbial adherence by coated polyglactin 910 suture with triclosan.

Edmiston et al [5], 2006, report that there are more studies to assess bacterial adherence and the antibacterial activity of a triclosan-coated polyglactin 910 (braided) suture against selected Gram-positive and Gram-negative clinical isolates from infect surgical wounds that reductions in both Gram-positive and Gram-negative bacteria such as *Staphylococcus aureus* - methicillin-resistant *S aureus* (MRSA), *S epidermidis* (biofilm-positive), and *Escherichia coli* - extended-spectrum beta-lactamase (ESBL) or producer. The adherences were observed on triclosan-coated sutures compared with non-coated material. After insertion of antimicrobial suture, the inert surface is rapidly coated with tissue proteins, including fibrinogen, fibronectin, collagen, and other soluble substrates, which function as adhesions for microbial attachment. In this study was designed to provide an in vitro evaluation of contaminated suture material in an environment mimicking the physiologic conditions within the surgical wound. For the suture material preconditioned in Bovine Serum Albumin (BSA), compared with non-conditioned suture material, there was approximately a 35% to 40% increased in staphylococcal and *E coli* adherence to the surface of both noncoated and triclosan-coated polyglactin 910 sutures. But, the BSA conditioning did not diminish the antiseptic activity of triclosan-coated sutures compared with the non-coated devices [5].

After antimicrobial suture was developed successfully, a new type of antimicrobial sutures were established. The monofilament suture, Monocryl and PDS, was used instead of braided suture, Vicryl, for decreased the capillary effect of braided suture and may more improve rate of the SSIs. Ming et al [14], 2007, report monofilament Poliglecaprone 25 suture with triclosan (Monocryl Plus) and latest new type of antimicrobial suture, Polydioxanone suture with triclosan (PDS Plus), in the next year 2008. Both of them have appropriate antimicrobial activity cover gram positive and gram-negative bacteria in vitro and in vivo study.

### 5.2 In Vivo Study

**Animal Study**

Storch et al [27], 2002, compare between the physical and functional properties of coated polyglactin 910 sutures, with and without triclosan by human assessment and instrument-based measurements. In this study, surgeons specializing in general, orthopedic, plastic, or gynecologic surgery evaluated the suture materials in an in vivo porcine model. The addition triclosan to coated polyglactin 910 sutures did not affect physical handling properties or performance characteristics based on the testing and evaluations performed. Barbolt [6], 2002, report chemical and safety from biocompatibility studies showed that coated polyglactin 910 suture with triclosan was non-cytotoxic, non-irritating, and not a chemical pyrogen. In addition, an intramuscular implantation study demonstrated a tissue reaction, a healing response, and an absorption profile comparable to current polyglactin 910 sutures. Triclosan has been evaluated for prolonged oral and dermal exposure in several species of animals and there was no evidence of carcinogenic potential in either species, and genotoxicity studies were negative. Reproductive toxicity studies did not reveal any evidence of teratogenic potential. Also, there was no evidence of skin sensitization potential in controlled studies. Pharmacokinetic studies have shown that triclosan is rapidly absorbed, well distributed in the body, metabolized in the liver, and excreted through a catheter. Sixteen animals were divided into two groups: traditional braided Polyglactin sutures; and Coated Vicryl Plus Antibacterial Suture. The animals were sacrificed, the sutures were removed, and counts were made of the number of bacteria adhered to them after 48 hours. A 98.2% reduction in CFU was recorded in the Coated Vicryl Plus Antibacterial suture group (P < 0.05). This study demonstrated that the presence of coated polyglactin 910 sutures with triclosan resulted in a 30.5-fold reduction in the number of recovered bacteria compared to standard coated polyglactin 910 sutures. Macro et al [19], 2007, use 20 Sprague-Dawley rats under simulated conditions of severe intra-operative contamination by contaminated suture wound with *Staphylococcus epidermidis* 100,000 CFU/cc, the antibacterial suture reduced the number of positive cultures after surgery by 66.6%. When these data was judged with the available clinical information, its use might contribute to reducing the number of infected implants by 25.8% [19].

Coated Vicryl Plus antibacterial suture would be effective against more than 50% of the bacteria that produce surgical infections [15]. The microbiological study showed that Coated Vicryl Plus Antibacterial suture effectively reduced the number of bacteria present in the wound. Gomez-Alonso et al [15], 2007, reports in vitro study demonstrated efficacy against both gram positive and gram-negative organisms. By exclusively using clinical isolates (from patients in Salamanca Clinic Hospital), the results obtained support the use of Coated Vicryl Plus Antibacterial...
suture in the hospital setting. In view of the results obtained, an efficacy profile may be established, defining Coated Vicryl Plus Antibacterial suture as an adequate option for suturing in general, digestive anastomosis, subcutaneous suturing and skin closure, among other applications.

Human Study

As previously mentioned above, FDA (US) has approved polyglactin 910 sutures coated with triclosan for commercial use since 2002 [11]. Table 1 show that there were eight reports in human used in the past ten years. Five studies favored in antimicrobial suture, two studies showed no difference and one study against this new suture. The first report was publish by Ford et al in 2005 [34] show prospective, randomized, controlled, open-label, comparative, single-center study was conducted on 147 pediatric patients (age 1-18 years) undergoing various surgical procedures with either polyglactin 910 sutures coated with antibiotic triclosan or polyglactin sutures without triclosan. The endpoints of this study focused on intraoperative handling and wound healing characteristics instead of surgical site infection that the aim of this investigated suture. For intra-operative handlings were favorable and not significantly different for both sutures, although coated polyglactin 910 sutures with triclosan received more “excellent” scores (71% vs. 59%). Wound healing characteristics were comparable for both sutures, except significantly fewer patients with triclosan sutures reported pain on day one compared with patients without triclosan sutures (p=0.01). The overall incidence of adverse events was 18%; none was device related, and there was no difference between treatment groups. This study was sponsored by industry for antimicrobial sutures.

Fleck et al [30], 2007, a retrospective study to evaluate reduction of sternal wound infection. A total of 479 patients underwent a cardiac surgical procedure. One hundred and three patients were closed with triclosan-coated suture material, whereas the remaining 376 patients had their incision closed with non-coated sutures. After closing the sternal bone with steel wires, the sternal fascia was closed with interrupted 2-0 Vicryl Plus antibacterial sutures (Vicryl Plus Antibacterial [Ethicon, Sommerville, New Jersey]). Thereafter the subcutaneous tissue was closed with 2-0 Vicryl Plus antibacterial in a continuous fashion. The skin was closed with 3-0 Vicryl Plus antibacterial intra-cutaneous or after the fashion of Donatti in redo cases or patients with diabetes mellitus. The study period, 24 patients had superficial (n = 10) or deep (n = 14) sternal wound infections. All those patients were closed with conventional suture material. In the triclosan group, no wound infection or dehiscence was observed during hospital stay and follow-up visits. This study was also evaluated the cost-effective for this operation. The cost of a patient with sternal wound infection is $11,200 plus the costs of the normal stay ($11,400), resulting in a total cost of $22,600. Total costs of sternal wound closure in 1,100 patients can be estimated as $23,100. When the cost was calculated, it showed the increase of costs with the triclosan-coated sutures. There was an increased cost for suture material of $9,900 per year. Calculated on 1,100 patients per year, the total costs of sternal wound closure would rise to $33,000. However, during the same period, a total of 40 patients sustained a sternal wound infection, which resulted in an increase in cost of $448,000. In an optimistic case, if the hospital can achieve a reduction of sternal wound infections of 50% (20 cases), that would result in a decrease of costs of $224,000 minus $9,900, or $214,100. Sternal wound infections are a major cause of morbidity and mortality after cardiac surgery. Although the frequency of sternal infection is reported to be low, between 0.7% and 3.3%, the current Centers for Disease Control (CDC) guidelines recommend the wound to be covered for 24 to 48 hours after surgery. A fibrin seal sanct the wound and thereby prevents the admission of bacteria. Several studies have been conducted to evaluate the effectiveness of certain dressings, but unfortunately owing to the lack of empirical evidence, a high variability exists in the type of dressing used.

Rozzelle et al [11], 2008, a prospective, double-blinded, randomized controlled trial evaluate reduction of CSF shunt infection following shunt procedures. The study enrolled 61 patients, among whom 84 CSF shunt procedures were performed over 21 months. The shunt infection rate in the study group was 2 (4.3%) of 46 procedures and 8 (21%) of 38 procedures in the control group (p = 0.038). There were no statistically significant differences in shunt infection risk factors between the groups (procedure type and time, age < 6 months, weight < 4 kg and recent history of shunt infection). No suture-related adverse events were reported in either group. Wound closure with antimicrobial suture was associated with a favor lower shunt infection risk than placebo suture wound closure in this study but statistic not significant due to small sample size. To be a cost-effective in the hospital, the hospital cost difference was only USD 4.95 more per antimicrobial suture wound closure for a routine shunt procedure. Treatment of one shunt infection can easily exceed USD 25,000 in direct costs (local institutional estimate) and probably incurs much greater indirect costs due to associated morbidity, lost productivity, and other factors. Considering only estimated direct costs, antimicrobial suture wound closure for CSF shunt surgery would be cost-effective at a number needed to treat of < 5000 (USD 25,000/ USD 5.00). On the basis of this study, the incremental cost of preventing one shunt infection is estimated to be < USD 181 by applying the upper limit of the 95% CI for the number needed to treat to the cost difference. To give this cost estimate some perspective, it is worth noting that the cost of a set of antibiotic-impregnated shunt catheters exceeds USD 181.
Table 1 Summary of clinical trial in antimicrobial suture

<table>
<thead>
<tr>
<th>Author</th>
<th>Funding</th>
<th>Year</th>
<th>Location</th>
<th>Study design</th>
<th>Population/operation</th>
<th>End point</th>
<th>Result</th>
<th>Conclusion</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford et al [34]</td>
<td>Grant from Ethicon, Inc.</td>
<td>2005</td>
<td>California, USA</td>
<td>RCT</td>
<td>147 pediatric/</td>
<td>Intra-operative handling and wound healing assessments</td>
<td>No different in intra-operative handling. Significantly fewer pains in patients treated with Polyglactin 910 sutures with triclosan (68% vs. 89%, p&lt;0.01).</td>
<td>Favored triclosan-coated sutures</td>
<td></td>
</tr>
<tr>
<td>Fleck et al [30]</td>
<td>Not shown</td>
<td>2007</td>
<td>Vienna, Austria</td>
<td>Retrospective</td>
<td>479 patients/</td>
<td>Sterna wound infection</td>
<td>Wound infection 0% in Vicryl Plus Convention group Wound infection 2A (superficial) 2.6% Wound infection 2B (deep) 3.7% (p=0.008)</td>
<td>Favored triclosan-coated sutures</td>
<td>Demographic data was statistic significance difference both group.</td>
</tr>
<tr>
<td>Rozzelle et al [11]</td>
<td>No funding</td>
<td>2008</td>
<td>New York, USA</td>
<td>RCT</td>
<td>84 procedures/</td>
<td>Shunt infection</td>
<td>The shunt infection rate in the study group was 4.3% and 21% in the control group (p = 0.038).</td>
<td>Favored triclosan-coated sutures</td>
<td>Stat. not significant</td>
</tr>
<tr>
<td>Mingmalairak et al</td>
<td>Thammasat University Fund</td>
<td>2009</td>
<td>Pathumthani, Thailand</td>
<td>RCT</td>
<td>100 patients/appendectomy</td>
<td>Surgical site infection</td>
<td>Rate of SSI Vicryl Plus:10% Vicryl: 5% (p=0.727)</td>
<td>Not difference</td>
<td>No complications in either group (allergies or adverse effects)</td>
</tr>
<tr>
<td>Deliaert et al [38]</td>
<td>Not shown</td>
<td>2009</td>
<td>Venlo, the Netherlands</td>
<td>RCT</td>
<td>26 patients/</td>
<td>Wound dehiscence</td>
<td>Rate of Wound Dehiscence: Vicryl Plus: 61.5% Vicryl: 27% (p=0.023).</td>
<td>Cautioned in triclosan-coated suture</td>
<td>With own control on contra-lateral breast</td>
</tr>
<tr>
<td>Justinger et al [16]</td>
<td>Not shown</td>
<td>2009</td>
<td>Homburg/ Saar, Germany</td>
<td>Retrospective with different time periods</td>
<td>2,088 patients/ midline laparotomy</td>
<td>Surgical site infection</td>
<td>SSI rate PDS loop 10.8% Vicryl Plus 4.9% (P &lt; .001)</td>
<td>Favored triclosan-coated sutures</td>
<td></td>
</tr>
<tr>
<td>Justinger et al [36]</td>
<td>No funding</td>
<td>2011</td>
<td>Homburg/ Saar, Germany</td>
<td>Retrospective with different time periods</td>
<td>839 operations/ transverse abdominal incision</td>
<td>Surgical site infection</td>
<td>SSI rate PDSII loop 9.2% Vicryl Plus 4.3% (p&lt; 0.005)</td>
<td>Favored triclosan-coated sutures</td>
<td>This study was extend period of study both end for more population to study.</td>
</tr>
<tr>
<td>Chen et al [37]</td>
<td>Not shown</td>
<td>2011</td>
<td>Taipei, Taiwan</td>
<td>RCT</td>
<td>241 patients/ wide excision of a head or neck cancer and reconstructive procedure</td>
<td>Surgical site infection</td>
<td>SSI rate Vicryl 14.7% Vicryl Plus 14.9% (P=0.05)</td>
<td>Not difference</td>
<td></td>
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Justinger et al [16], 2009, this is the large cohort to evaluated the effect of antibacterial-coated sutures for abdominal closure. They performed 2,088 operations between October 2004 and September 2006 via midline incision and prevent wound infections in different kinds of abdominal surgery, including colorectal, hepatopancreatic, and vascular surgery. In the first time period (October 2004 to September 2005 = TP1), a PDS II loop suture was used. In the second time period (October 2005 to September 2006 = TP2), we used Vicryl plus. Using a PDS loop suture for abdominal wall closure in TP1. 10.8% of patients with wound infections were detected. The number of patients with wound infections decreased in TP2 using Vicryl plus for abdominal wall closure to 4.9% (P < .001) despite no other changes in protocols of patient care. Other risk factors for the development of site infections were comparable in the two groups. The use of antibiotic-coated loop suture for abdominal wall closure can decrease the number wound infections after abdominal surgery. Although this study was done in a single center in Germany over two different time periods and using two different types of suture material with high volume of sample size. Although these findings of the study are impressive, the design and data analysis appear to be still sub-optimal because of no randomization of the patients, lack of microbial confirmation and multivariate analysis. Additionally, their strategies for the management of contaminated wounds are not shown, which greatly influence the outcomes of such wounds. Despite an increase in the rate of wound infection in the PDS group, the duration of hospital stay was not prolonged in this group, suggesting that complications other than wound infection might occur more frequently in the triclosan coated group. Abdominal wound dehiscence, which is a deep incisional surgical site infections and a very serious wound complication, appears to be more related to the suture materials used for transfascial mass closure when compared with the association between these suture materials and superficial incisional SSIs. So this study should show whether antibiotic coating of transfascial sutures could decrease the rate of wound dehiscence [35].

However, Justinger et al [36], 2011, has extended his study between October 2003 and October 2007 (previous study reported between October 2004 and September 2006) and focused in transverse abdominal incision instead midline incision as previous study [16]. 839 operations were performed using a transverse abdominal incision. In the first time period, a PDSII loop suture was used for abdominal wall closure. In the second time period, we used Vicryl plus. Wound infections after transverse laparotomy. 409 Using a PDSII loop suture for abdominal wall closure in the first time period, 9.2% of the patients developed wound infections. In the second time period, 430 using Vicryl plus, the number of wound infections decreased to 4.3% (p< 0.005). Both groups were comparable regarding risk factors despite no other changes in protocols of patient care. The major clinical finding of this study is the superiority of braided Vicryl plus sutures over PDS sutures in relation to wound infections after a two-layered closure of transverse laparotomy in patients undergoing hepatobiliary resections.

Two randomized control trails show no statistical difference in both group. First, Mingmalairak et al [10], 2009, report a prospective, randomized, controlled, double blind, comparative, a single center study was conducted to assess the efficacy of an antibacterial suture (polyglactin 910 coated with triclosan) compared to uncoated polyglactin 910 sutures in reducing rates of SSI in patients undergoing appendectomy. Surgeons and assistants were blinded to suture type as similarity in appearance made the two products indistinguishable. Baseline patient characteristics did not difference between both group. The rate of SSI was not statistically significantly different between the two treatment groups, nor was the complication rate after one year. The authors concluded that polyglactin 910 coated with triclosan was safe in surgical practice, with a comparable outcome to polyglactin 910 but that more study was needed to confirm this.

Second, Chen et al [37], 2011, this prospective study was evaluated the effect of triclosan-coated sutures on surgical wide excision of a head or neck cancer and reconstructive procedures. 241 patients were included in this study, divided into two groups by flip of a coin. The Triclosan group contained 112 patients, whose surgical wounds were closed with Triclosan-coated sutures (Vicryl Plus). The control group included the remaining 129 patients, whose surgical wounds were closed with conventional Vicryl sutures. The results showed cervical wound infection rate was 14.9% (17/112) in the Triclosan group and 14.7% (19/129) in the control group, and these rates were not significantly different. Tumor stage and delayed intra-oral flap healing were independent risk factors for cervical wound infection. In this study, Triclosan-coated Vicryl sutures did not reduce the infection rate of cervical wounds after head or neck cancer surgery. The effectiveness of this suture material in head and neck cancer surgery should be considered with caution.

The study showed negative result, which was also stated by Deliaert et al in 2009 [38]. The study investigated the effect of triclosan on wound healing a double blind prospective pilot study in women undergoing a breast reduction was performed. Each patient was her own control. After randomization the TC-coated sutures were used either on the left or right side. The contralateral side was used as the control. The incidence of dehiscence was studied. The result showed twenty-six patients were included. In the triclosan breasts there was a wound dehiscence in 16 cases, whereas in the control breasts in seven cases a dehiscence was observed (P=0.023). These results suggest that triclosan-coated sutures should be used with caution. These sutures have already been introduced on to the market without good clinical studies and might have potential adverse effects as shown by these data. The bilateral dehiscence in five cases found that four unilateral dehiscent cases in the triclosan group (p=0.023). The limitation of this study was small sample size but a double blind randomized design in which each patient was their own controls have value because each patient is her own control.
5.3 Cost Effectiveness

It is estimated that 750,000 surgical site infections occur in the US each year, using 3.7 million extra hospital days and costing more than USD 1.6 billion in excess hospital charges each year [5]. In some serious complications can occur with infection in major surgery. In spinal fusion, one case of SSIs increased hospitalization by 20.5 days and had median attributable costs of USD 11,001[19]. A recent analysis of the cost of SSIs in patients undergoing major surgery in a tertiary hospital found a SSIs incidence of 9% [39]. The hospital stays of patients with SSIs were 14 days longer than those without an SSIs, with additional hospital costs of USD 10,232 per patient (USD 97,433 including indirect social costs). A small hospital performing 20,000 surgical procedures annually with an infection rate of 5% would have 1000 SSIs. Assuming a SSIs reduction using triclosan-coated sutures of only 10%, use of such a suture, based on current costs, would avoid 100 SSIs yielding a cost saving of USD 97,000. A sensitivity analysis can also be performed when the SSIs rate using triclosan-coated sutures is reduced by only 1%; this still offers a net benefit of USD 76,000. After procedures, which have a higher SSIs rate the benefits could be even greater [39].

A follow-up study from a recent randomized controlled trial conducted at the Women and Children’s Hospital of Buffalo that investigated the use of antimicrobial sutures (AMS) for wound closure during cerebrospinal fluid shunting procedures. This study found that the treatment and management of a shunt infection resulted in a 5.3-fold increase in hospital charges. Without the use of AMS, the average total cost per procedure was USD 36,839. The use of AMS resulted in a significant reduction in the mean total cost per procedure to USD 19,412 (p = 0.038). Potential healthcare savings associated with reduced infection rates are significant. These calculations demonstrate the profound economic effect a reduction in shunt infection rates may have on a healthcare system [7].

5.4 Commercial Availability

Ethicon, Inc. is currently the only manufacturer of commercially available antimicrobial suture [26]. Actually before that there had many report from Russia about antimicrobial suture since 1976 [40]. There also had report commercial name “Capromed” during 1991-1999 but all of that report in Russian and no report after that time [41-43].

Figure 2. The characteristic similarity of Vicryl and Vicryl Plus in commercial market.

All products have only added triclosan in the original suture, so both of products have similar package and feature (as shown in Figure 2). Available products from Ethicon, Inc. are below:
- Vicryl Plus (polyglactin 910 with triclosan) [10]: Polyfilament absorbable sutures.
- Monocryl Plus (Poliglecaprone 25 with Triclosan) [14]: Monofilament absorbable sutures.
- PDS Plus (Polidioxanone with Triclosan) [33]: Long acting monofilament absorbable sutures.

6. Potential risks of triclosan-coated devices and implants

Although a review of 30 years of triclosan use showed there was no risk of resistance, carcinogenic potential, genotoxicity, skin sensitisation and pharmacokinetic studies have shown that triclosan is rapidly absorbed, well distributed, metabolised in the liver, and excreted by the kidneys and no association between triclosan and antibiotic resistance and the susceptibility of bacteria isolated in the community has been found [7, 29, 44]. With the increasing use of this agent in pharmaceutical and hygiene products and more recently household goods, many report and concern of this product have increasing.

There have a study show that triclosan enhances the production of chloroform when contact with chlorine, which is classified by the Environmental Protection Agency (EPA) as a probable human carcinogen. Fiss et al [45], 2007,
illustrate that under some circumstances, triclosan triggered the production of chloroform in amounts up to 40% higher than background levels in chlorine-treated tap water. But another study published the same year showed no formation of detectable chloroform levels over a range of expected tooth-brushing durations among subjects using toothpaste with triclosan and normal chlorinated tap water [1, 45]. There have studies findings regarding links between triclosan and adverse health effects in animals. One study, for example, associated exposure to low levels of triclosan with disrupted thyroid hormone associated gene expression in tadpoles, which encouraged them to prematurely change into frogs, while another linked triclosan exposure with reduced sperm production in male rats. [46].

The widespread use of triclosan-coated sutures is increased recovery of triclosan resistant pathogens such as *Pseudomonas aeruginosa*. But recent studies suggested that sub-inhibitory or long-term exposure to triclosan is not associated with diminished triclosan activity or increased antimicrobial resistance, as measured by minimal inhibitory concentrations in *S. aureus* [47]. Although these studies suggest that the acquisition of microbial resistance to triclosan appears to be very low based on minimal inhibitory concentration data, we should not forget that selected microbial populations (i.e. *Pseudomonas aeruginosa*) have been found to be resistant to various antiseptic agents, including triclosan, so the potential risk of encountering a clinical strain resistant to triclosan is unlikely to be zero [5]. Although there are a few reported cases of contact dermatitis in humans from triclosan containing products, it is considered that triclosan presents little or no contact sensitization hazard for patients, particularly at the low concentrations of triclosan present in suture material [6].

For many concerned, in April 2010 the US Food and Drug Administration (FDA) announced it is conducting a scientific and regulatory review of triclosan in FDA-regulated products, with publication of results expected in spring 2011. The agency also is collaborating with the U.S. Environmental Protection Agency (EPA) specifically to study the potential endocrine-disrupting effects of the compound [1].

### 7. Conclusion

A major complication in surgical site infections still exists, which develop morbidity and mortality each year. Antibacterial sutures, which are sutures coated with antibiotics, were developed to help the wound healing by reducing the risk of surgical site infections. In vitro study, this suture has shown an appropriate efficacy to reduce the infection from suture related infections. But this promising was not clear in clinical studies. After this suture was launched into a commercial market in the past 10 years, the effectiveness of antibacterial sutures study has been continued and the results are still unclear, thus complications can occur. It is, therefore, necessary to examine the evidence regarding the clinical effectiveness and adverse effects of antibacterial sutures. Despite the fact that surgical wound infection increased cost, the cost-effectiveness of antibacterial-coated sutures remains uncertain. Higher quality research on the effectiveness of antibacterial sutures is needed. It is of vital important to confirm the result of SSIs in clinical trial study before using in patients as in medication process. However, principles of effective wound care are still a priority for a healthy wound closure.

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### References

Aylwarda LL, Haysb SM. Consideration of dosimetry in evaluation of ToxCast™ data.

Fiss EM, Rule KL, Vikesland PJ. Formation of chloroform and other chlorinated byproducts by chlorination of triclosan.

Storch M, Bhargava HN, Leonard PA. Triclosan: applications and safety.


