Continuous High-Pressure Negative Suction Drain: New Powerful Tool for Closed Wound Management: Clinical Experience

by

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Major in Medicine
Department of Medical Sciences
The Graduate School, Ajou University
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Continuous High-Pressure Negative Suction Drain:
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Background & Aims: Although various reconstructive flap surgeries have been successfully performed, there still are difficult wound complications, such as seroma formation, wound margin necrosis, delayed wound healing, and even flap failures. The negative-pressure wound therapy has been described in detail in the literature to assist open chronic/complex wound closure in reconstructive surgery. However, the negative-pressure wound therapy was difficult to be applied under the incisional closed wounds.

Methods: A total of 23 patients underwent the various reconstructive flap surgeries with continuous high-pressure negative suction drain. Instead of using regular suction units, Barovac® (50 – 90 mmHg, Sewoon Medical, Seoul, Republic of Korea) drainage tubes were connected to the wall suction unit, providing continuous high-powered negative pressure. In addition, continuous subatmospheric suction pressure (100 – 300 mmHg) was applied. Outcome of the measures was obtained from the incidence of seroma, volume of postoperative drainage, hospitalization period, and incidence of other typical wound complications. Dead space was evaluated postoperatively with ultrasonography.

Results: Using continuous high-pressure negative suction drain, successful management of seroma was obtained without any major complication such as wound infection, flap loss, and wound margin necrosis, except for only 1 case of seroma after discharge from the hospital. The indwelling time of the
drain in the latissimus dorsi donor site was significantly reduced in comparison with the authors’ previous data ($P = 0.047$). The volume of drainage and hospitalization period were also reduced; however, these were not statistically significant. The dead space with continuous high-pressure negative suction drain was more reduced than in the control group in the immediate postoperative period and confirmed with ultrasonography.

**Conclusions:** Continuous high-pressure negative suction drain might be the simple and powerful solution in the management of challenging closed wounds.

**Key Words:** Seroma, Wall suction, Continuous high-pressure negative suction drain
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I. INTRODUCTION

Nowadays, various reconstructive flap surgeries have been successfully performed to cover the challenging wounds that require extra care. There are some complications – donor site seroma in the latissimus dorsi flap, seroma in the abdominoplasty area, hematoma under the flaps, wound margin necrosis, partial flap loss, repetitive seroma, and even flap necrosis. Among several different techniques, which have been documented in the management of these complications, some preventive maneuvers are not uniformly successful.

Negative-pressure wound therapy (NPWT) is an adjunct therapy using negative pressure to remove fluid from open wounds through a sealed dressing (reticulated open-cell polyurethane ether foam) and a specialized tube that is connected to a suction unit. The technique is designed to remove chronic edema fluid, thereby decreasing the afterload to blood flow, resulting in increased localized tissue perfusion (Timmer et al., 2005; Scherer et al., 2008; Schintler, 2012; Argenta et al., 2006). With applied negative-pressure forces, the formation of granulation tissue is enhanced (Timmer et al., 2005; Schintler, 2012; Lee et al., 2011; Saxena et al., 2004). The negative-pressure technique has been demonstrated to be an extremely efficacious method to stimulate healing by secondary intention (Argenta et al., 2006; Lee et al., 2011; Mendonca et al., 2006). This effective technique has been mostly applied on challenging wounds such as exposed complex and chronic wounds, or on skin graft area, or closed surgical incision sites (Lee et al., 2011; Mendonca et al., 2006; Kilpadi and Cunningham, 2011; Schmedes et al, 2012; Ubbink et al, 2008; Argenta and Morykwas, 1997).

However, many articles reported about its application to open complex
wounds or over the closed surgical incision sites. This report reviews such articles that state that using negative-pressure technique successfully prevented the complications in various flap surgeries.
II. PATIENTS AND METHODS

This study included 23 patients who underwent the reconstructive surgery from September 2011 to January 2013 (Table 1). Breast reconstruction, abdominoplasty, giant mass excision, gynecomastia correction, traumatic avulsed flap reconstruction, and reconstruction for pressure sore were performed as the reconstructive surgery.

Table 1. Diagnosis and operation data of total patients

<table>
<thead>
<tr>
<th>No.</th>
<th>Sex/Age</th>
<th>Diagnosis</th>
<th>Op. name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F/42</td>
<td>Invasive ductal carcinoma, breast, Lt.</td>
<td>Total mastectomy and immediate reconstruction using extended latissimus dorsi myocutaneous flap</td>
</tr>
<tr>
<td>2</td>
<td>F/49</td>
<td>Invasive ductal carcinoma, breast, Lt.</td>
<td>Total mastectomy and immediate reconstruction using extended latissimus dorsi myocutaneous flap and cohesive-gel filled breast implant</td>
</tr>
<tr>
<td>3</td>
<td>M/68</td>
<td>Madelung’s disease, posterior neck</td>
<td>Mass excision, excess skin removal and coverage using local flap advancement</td>
</tr>
<tr>
<td>4</td>
<td>F/48</td>
<td>Tubular carcinoma, breast, Lt.</td>
<td>Total mastectomy and immediate reconstruction using extended latissimus dorsi myocutaneous flap and cohesive-gel filled breast implant</td>
</tr>
<tr>
<td>5</td>
<td>F/19</td>
<td>Avulsion flap injury, temporoparietooccipital area, scalp, Lt.</td>
<td>Arteriorrhaphy, debridement and repair</td>
</tr>
<tr>
<td>6</td>
<td>M/27</td>
<td>Gynecomastia, bilateral</td>
<td>Subcutaneous mastectomy</td>
</tr>
<tr>
<td>7</td>
<td>M/18</td>
<td>Gynecomastia, Lt.</td>
<td>Subcutaneous mastectomy</td>
</tr>
<tr>
<td>8</td>
<td>M/57</td>
<td>Pressure sore, coccygeal area, greater trochanteric area, Rt. and buttock area, Lt.</td>
<td>Debridement, bursectomy and coverage using local flap rotation and advancement</td>
</tr>
<tr>
<td>9</td>
<td>F/19</td>
<td>Huge fibrolipoma, upper back, Rt.</td>
<td>Mass excision and repair</td>
</tr>
<tr>
<td>10</td>
<td>F/48</td>
<td>Invasive ductal carcinoma, breast, Lt.</td>
<td>Total mastectomy and immediate reconstruction using extended latissimus dorsi myocutaneous flap and cohesive-gel filled breast implant</td>
</tr>
<tr>
<td>11</td>
<td>F/39</td>
<td>Postmastectomy status, breast, Rt.</td>
<td>Delayed reconstruction immediate reconstruction using extended latissimus dorsi myocutaneous flap and cohesive-gel filled breast implant</td>
</tr>
<tr>
<td>12</td>
<td>F/38</td>
<td>Intraductal carcinoma, breast, Lt.</td>
<td>Total mastectomy, sentinel lymph node biopsy, and immediate reconstruction using ipsilateral pedicled TRAM flap</td>
</tr>
</tbody>
</table>
When the operative fields were closed after the main operative procedures, Barovac® (Sewoon Medical, Seoul, Republic of Korea) drain tubes, which are perforated polyvinyl chloride suction drains (Fig. 1), were inserted into the cavity. In place of the regular suction unit providing 50 to 90 of mmHg negative pressure, the drains were connected to the continuous high-pressure suction wall suction unit (Fig. 2). Negative pressure ranged from 120 to 300 mmHg, minimal pressure, to maintain the stable flap base and to reduce dead space. In the larger operative area, the higher pressure was applied. There were no additional procedures to prevent seroma, such as
quilting sutures or fibrin glue injection. To evaluate the dead space in the operative sites, ultrasonography was performed. Patients were treated with the standard conventional postoperative care (Stebbins et al., 2011). Amount of the volumes and duration of wound drainage were recorded postoperatively. When drainage was less than 20 mL for a 24-hour period, the drainage tubes were removed (Cha et al., 2012; Shin et al., 2012).

Fig. 1. Barovac® (Sewoon medical, Seoul, Korea) drain tubes are perforated polyvinyl chloride suction drains providing 50 – 90 mmHg of negative pressure.
Fig. 2. Wall suction unit provides high pressure negative power ranging from 0 – 300 mmHg.
Outcome of the measures was the volume of drainage output, the length of time that the drain remained in the site, hospitalization period, and evaluation of dead space using ultrasonography. In addition, any complications, including recurred seroma, wound dehiscence, infections, and delayed wound healing, were studied. In the group of the breast reconstruction with latissimus dorsi flap, each patient was compared with the patients who had undergone the same surgical procedures without high-pressure negative suction drain.

Statistical analysis was performed using the Statistical Package for the Social Sciences version 13.0 (Windows version, Statistical Package for the Social Sciences Inc, Chicago, IL). The Mann–Whitney test was used to analyze the effects of interventions.
III. RESULTS

Continuous high-pressure negative suction drain was applied to 23 patients who underwent reconstructive flap surgery. Among them, there were 8 breast reconstructions with extended latissimus dorsi flap and cohesive gel-filled implant, 1 breast reconstruction with pedicled transverse rectus abdominis myocutaneous flap, 2 abdominoplasties, 3 giant benign mass removals, 2 traumatic avulsed flap reconstructions, and 8 other cases. The authors used the continuous high-pressure negative suction drain as an adjuvant method. There was no typical wound complication, such as wound infection, flap loss, and wound margin necrosis, except for 1 recurred seroma case, which was easily solved with the one-time aspiration and compressive dressing. However, in the control group, 8 in 10 cases had seroma formation, and serial aspiration with compression dressing was performed to treat the seroma. In extended latissimus dorsi flap donor site, drainage volume was significantly reduced in comparison with recent data of 10 patients from the authors’ previous study. These patients underwent a conventional donor site closure without quilting sutures or fibrin glue injection.

The total drainage volumes were decreased with this method, from a median of 680.00 (269.5 - 3127.9) mL to 438.85 (163.0 - 1243.0) mL in extended latissimus dorsi flap donor site. The median indwelling period of the drains was 6.0 (3 - 10) days with the wall suction group and 9.0 (8 - 19) days with the control group (Table 2 and Fig. 3). The median hospitalization period of the wall suction group (8 days) was shorter than that of the control group (12 days); however, this was not statistically different (P = 0.183). Ultrasonography was examined immediately after the operation. Compared with the regular suction unit, dead space was definitely reduced (Fig. 4).
Finally, wounds lasted for 6 months to 18 months.

Table 2. Comparison of outcome measurements in extended latissimus dorsi flap donor site

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Group 1: Wall suction (n=8)</th>
<th>Control 2: Control (n=10)</th>
<th>p-value</th>
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</thead>
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<tr>
<td>Cumulative drainage fluid</td>
<td>435.85 (163 – 1243.0)</td>
<td>680.00 (269.5 – 3127.9)</td>
<td>0.441</td>
</tr>
<tr>
<td>volume in donor site (mL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day of drain removal (day)</td>
<td>6.0 (3 – 10)</td>
<td>9.0 (7 – 19)</td>
<td>0.047</td>
</tr>
<tr>
<td>No. of seroma formation (n)</td>
<td>1</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented in the median value (range).
Fig. 3. Volume of drain output until drains in control and wall suction groups were removed.
Fig. 4. Ultrasonography was examined immediate postoperatively. Compared with regular suction unit (left panel), both dead space and the gap between layers were definitely reduced (right panel). Red arrows indicate dead space, and blue arrows indicate drainage tube.
IV. CASE REVIEWS

Patient 1

A 43-year-old woman was examined in the clinic for reconstruction of her right breast. She had undergone modified radical mastectomy for intraductal carcinoma 5 years ago. Breast reconstruction using extended latissimus dorsi fasciocutaneous flap and cohesive gel-type breast implant (Mentor, Santa Barbara, CA; 175mL) was performed. When the donor site was closed, simple suture method without quilting suture was applied, and the drainage tube was placed into the donor site with the connection to the high-pressure negative suction unit at 300 mmHg. The drainage volume was 134 mL on the first postoperative day and decreased rapidly since the second postoperative day. On the fifth postoperative day, the drainage was 22 mL during a 24-hour period, so the drain was removed on the sixth postoperative day. There were no wound-related problems and no seroma formation.

Patient 2

A 19-year-old woman had a traffic accident and was hospitalized for multiple rib fractures, liver contusion, and left parietotemporalfasciocutaneous avulsion flap injury. The superficial temporal artery was transected. In emergent operation, arteriorrhaphy was done successfully. After dirty margin debridement, the avulsed flap was repaired with simple silastic drains. Despite a successful operation, a large amount of serous drain was noted along the silastic drains.

On the fourth postoperative day, the drainage tube was placed under the flap area with the connection to the continuous high-pressure negative
suction unit at 120 mmHg. On the fifth postoperative day, the drainage volume was 25 mL. Drainage volume was decreased daily and was 5 mL on the ninth postoperative day, so the drain was removed on the 10th postoperative day.

**Patient 3**

A 42-year-old woman had undergone breast reconstruction using extended latissimus dorsi fasciocutaneous flap and cohesive gel-filled implant. She had been visiting the outpatient clinic for repetitive aspiration therapy for chronic seroma on the donor site for 2 weeks after discharge. The mean aspiration volume was 26.5 mL. She was admitted, and 1 drainage tube was inserted and connected to the continuous high-pressure negative suction unit at 200 mmHg. On the third day after application, drainage volume was decreased to nearly 0 mL. After 2 more days, the drainage tube was removed, and compressive dressing was applied. Chronic seroma was successfully resolved, and there was no recurrence.

**Patient 4**

A 54-year-old man had a chronic recurred pressure sore on the coccygeal area. He had paraplegia for 20 years. Grade IV pressure sore was noted. Debridement and conventional NPWT with intravenous antibiotics were applied for 2 weeks. Despite repetitive adjuvant therapy, there was not enough fresh granulation tissue. After dirty margin debridement, V-Y gluteus maximus musculocutaneous flap rotation was performed using 2 drainage tubes inserted and connected to a high-pressure negative suction unit at 300 mmHg. Flap size was approximately 20 x 10 cm². The flap seemed stable and fixed to the basal layer without dead space. Drainage volume decreased day
by day and was 15 mL on the 10th postoperative day; therefore, the drain was removed on the 14th postoperative day. There were no wound complications including wound margin dehiscence and necrosis.
V. DISCUSSION

Treatments of wounds, especially hard-to-heal wounds, have been the working basis of plastic surgery since the start of this specialized discipline (Schintler, 2012). However, reconstructive flap surgery is one of the main methods for these complicated wounds and many related complications - seroma/ hematoma, wound margin dehiscence, delayed wound healing, and even flap failures.

Among these complications, seroma is one of the common postoperative complications in reconstructive surgeries. The etiology behind seroma formation remains unclear. Several theories have been suggested that include disruption of vascular and lymphatic channels, shearing effects between subcutaneous surfaces and underlying musculatures, creation of a surgical dead space, and an effect of inflammatory mediators generated subsequent to tissue damage (Shin et al, 2012; Arrawal et al., 2006; Taghizadeh et al. 2008). The main concepts of the prevention and control of the seroma are the reduction of mechanical shearing effects and promotion of wound healing (Cha et al. 2012; Taghizadeh et al. 2008; Ali et al, 2010; Nahas et al., 2007).

In the various methods of preventing seroma formation, quilting suture and fibrin sealant have been tried in many groups (Cha et al. 2012; Shin et al, 2012; Ali et al, 2010; Nahas et al., 2007; Andrades et al., 2007). Quilting suture between skin flaps and underlying layers is commonly used to reduce seroma formation, and studies have shown this method to be effective in a clinical setting (Nahas et al., 2007; Andrades et al., 2007). It might eliminate the mechanical shearing force and dead space. However, this technique may lengthen operative time and need to be placed very accurately,
especially when large skin paddles are harvested (Cha et al. 2012). Fibrin sealant, a component adhesive tissue composed of fibrinogen and thrombin, has been used in a number of surgical settings primarily to achieve hemostasis and seal tissues. The mode of action of the fibrin sealant is two pronged: it reduces the dead space between 2 planes by means of tissue adhesion, which coaps the elevated skin flap to the underlying tissues, and it reduces hematoma and serous oozing from the involved surfaces by enhancing hemostasis and blocking the lymph channels responsible for drainage into the operative site (Cha et al. 2012; Shin et al. 2012; Ali et al. 2010). Some studies have reported that fibrin sealant was found to be effective in reducing wound drainage or seroma formation (Shin et al., 2012; Ali et al., 2010). In contrast, it was not found to be effective in other studies. In conclusion, fibrin sealant does not produce uniform results yet (Cha et al. 2012).

Authors paid attention to the method that reduces mechanical shearing effects and promotes wound healing. The use of negative pressure therapies in wound healing was first described in the early 1990s and has subsequently been adopted in the treatment of complex surgical and traumatic wounds (Lee et al. 2011). During the past decade, NPWT has gained favor in a wide variety of fields. Negative-pressure wound therapy is thought to yield wound-healing benefits by increasing blood flow, promoting angiogenesis, modulating inhibitory contents in wound fluid, and inducing cell proliferation (Timmers et al., 2005; Schitler, 2012; Argenta et al., 2006; Saxena et al., 2004; Argenta and Morykwas, 1997). Other reported effects of NPWT include tissue deformation with stretching of individual cells, thereby promoting cellular proliferation in the wound microenvironment (Saxena et al., 2004).

Therefore, negative-pressure therapy for both prevention of seroma/
hematoma and promotion of wound healing was refined to apply through the drainage tubes without the polyurethane foam. The usual negative drainage system provides only 50 to 90 of mmHg negative pressure. Authors tried to apply higher negative pressure continuously using wall suction units, which provide a maximum of 300 mmHg. The larger the area of the flap was, the higher the pressure was applied. Larger areas such as abdominoplasty area, latissimus dorsi flap donor site, and giant lipoma excision site were very effective. In contrast, the effectiveness in relatively small areas was not different between low pressure and high pressure. In our experiences, effective negative pressure per area might be the keystone of this trial.

On applying high-pressure negative suction drain under the flaps, the flaps seemed to be more stabilized to fix the underlying tissues than were other methods such as quilting sutures (Fig. 5). Ultrasonography showed that dead space and the gap between tissues of each layer were decreased dramatically (Fig. 4). Pressure level was changed case by case. The days of indwelling of the wall suction group were significantly shorter than those of the control group (P = 0.047). However, the median of total drainage volume and hospitalization period seemed to decrease, which was not statistically significant (P = 0.441 and 0.183, respectively). This might be the result of the small numbers of patients in both groups. No serious wound complications such as wound dehiscence, flap margin necrosis, or flap loss were found. It means that our refined technique might reduce mechanical shearing effects and promote wound healing effectively. The advantages of continuous negative suction over conventional suction drains are (1) keeping vacuum state of closed space; (2) keeping zero dead space; (3) rapid decrease of serum products; (4) helpful to the flap success for difficult wounds; (5) and, consequently, rapid reduction of the hospitalization time.
In the result of our study, a large flap wound or donor site that needs continuous compression to reduce dead space can be a good indication of high-pressure negative suction drain. Latissimus dorsi flap and transverse abdominis flap donor site, flap area after the pressure sore reconstruction, abdominoplasty area, and defect after huge mass excision were good examples. As the disadvantage of this method, it is presumed that high-pressure negative suction can induce ischemia of fat tissue and fat necrosis. However, we think that our suction drain is too small to induce a large area of fat necrosis, so dead space will not be formed by a small amount of fat necrosis.

Fig. 5. On applying high pressure negative suction therapy under the skin flap at 150 ~ 160 mmHg, the flaps were more stabilized to fix the underlying tissues (blue arrows) than other methods such as quilting sutures.
Before using high-pressure negative suction drain, there are a few things to be aware of. If there is a bleeding vessel in the wound, high-pressure negative suction can cause massive bleeding. Thus, before applying high-pressure negative suction drain, meticulous hemostasis of the flap and recipient wound is mandatory. In addition, negative suction drain with the highest pressure (300 mmHg) can induce painful sensation for the patient. Therefore, if the patient complains of pain, gradually increasing the negative pressure will be helpful. Because local high pressure (>200 mmHg) can induce drain tube collapse near the wall suction bottle, regular checking of the tube is needed, and it has to be changed to a thicker tube when there is repetitive collapse. In addition, for the free flap or the pedicled flap wound, negative suction drain near the anastomosis site or the flap pedicle can cause vascular collapse because of high pressure. Therefore, suction drain should be kept away from the anastomosis site or the flap pedicle.

In our experience, the application of negative-pressure therapy under the clean closed wound is a new powerful technique in the postoperative management of various flap surgeries, which may decrease wound complications. This is the first study to report such a novel use of negative suction drain therapy. A larger group of patients and prospective randomized studies for appropriate pressure level are needed for our refined technique.
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고압력 연속 음압 흡입기를 이용한,
패쇄 창상의 치료의 새로운 해결방법

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신 승 준
(지도교수 : 박 명철)

배경 및 목적: 현재까지 다양한 재건 피판 수술이 소개되고 그 성공례가 보고되고 있지만 장액종의 형성, 창상의 변연부의 피사, 지연성 회복, 또는 피판의 피사와 같은 어려운 합병증들이 꾸준히 있어오고 있다. 음압치료는 이제까지 재건수술에 있어서 개방성 창상의 회복을 도와주는 것은 여러 문헌에 소개되어왔지만, 음압치료가 패쇄적인 창상에 직접적인 적용을 하는 것은 어려움이 있어왔다. 이에 본 연구에서는 이러한 창상의 회복에 대한 새로운 방법을 고안하여 성공적인 결과를 보고하고자 한다.

방법: 다양한 재건수술을 받은 환자 중 고압력 연속 음압 흡입술을 받은 23명의 환자를 대상으로 하였다. 일반적인 흡입기 대신 고압력 음압을 지속적으로 제공해 줄 수 있는 음압기를 사용하였다. 또한 음압은 100 – 300 mmHg의 범위로 적용하였다. 결과의 측정은 장액종의 반도, 수술 후 배액량, 병원 재원 기간, 그 외의 다른 창상과 연관된 합병증을 수집하여 평가하였다. 또한 수술 후 발생하는 사고는 초음파를 통하여 평가하였다.

결과: 고압력 연속 음압 흡입술을 통하여 치료한 환자들은 창상 감염, 피판 피사와 같은 주요 합병증은 발생하지 않았지만, 단 1례의 경우 퇴원 후 지연성으로 장액종이 발생하였다. 광배근의 공여부에서 삽입한 배액관의 유지기간의 경우
저자들의 과거 자료와 비교 시 의미 있게 감소함을 알 수 있었다 \((P = 0.047)\). 배액량과 재원기간 역시 감소함을 나타내었으나 통계적인 유의함은 없었다. 초음파를 통해 평가한 숭후 발생한 사상의 경우 대조군과 비교 시 크게 감소하였다.

결론: 고압력 연속 음압 흡입치료는 간단하지만 패쇄적 창상의 치료에 있어 강력한 치료 방법이다.

핵심어: 장액종, wall suction, 고압력 연속음압 흡입기