Medical terminology associated with Negative Pressure Wound Therapy (NPWT). Understanding and Misunderstanding in the field of NPWT.

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Abstract – Introduction of NPWT for clinical practice in the management of complex wounds significantly influences the progress of wound treatment. The excellent long-term results using this method in the field of chronic and complicated wounds, has made this technique widely accepted for a number of indications and varying branches of medicine. The widespread availability of this method thus resulted in new medical terminology which so far were rarely used or remained unknown. For the purpose of clear and unequivocal communication between medical staff-patients as well as among medical personnel, there is a need for a unified nomenclature regarding NPWT and the understanding of its principles. Below we present a synthesis of the basic terms used for NPWT. Continuous progress of this method as well as the innovations associated with therapy constantly make a list of new terms longer and longer. Apart from the theoretical aspects presented in this paper founded as a crucial elements to clearly understanding the principles of the method, we emphasized some useful aspects to be essential from the practical point of view. We believe that this study will help to understand the mechanisms of NPWT as well as systematize the existing knowledge about NPWT.

Keywords — medical terminology - negative pressure wound therapy - NPWT - complex wounds - sub-atmospheric pressure

I. INTRODUCTION

Medical terminology used in everyday practice may bring about a lot of misunderstandings. Inconsistencies and difficulties of medical nomenclature may be the cause of disinformation with its potentially terrible consequences. The misunderstandings are commonly found in a doctor-patient relationship. For example, Hume et al. presented a study where 28% of patients undergoing anesthesia, incorrectly interpreted the term "fasting." Term seemed to be clear and easy to understand in general. Miscommunication may happen also among medical staff regarding advanced procedure, especially when it concerns disease rarely present, associated with a sophisticated technique, or just introduced for general practice. Medical progress in general, in all fields of medicine determines the constant need to follow updates, recommendations and algorithms.

The introduction of NPWT in the early 90s to clinical practice significantly improved the management of complex wound. Despite initial skepticism associated with the principles of therapy and first outcomes, shortly thereafter however the therapy has become the gold standard technique supplying complex wounds. Moreover, it has become the method of choice in many diseases which would otherwise be impossible to heal using standard procedures or even initially founded as a contraindication. Technical improvement of NPWT caused somewhat of a revolution regarding complex wound healing as well as the evolution of medical terminology. Despite the worldwide availability of NPWT, the terminology associated with this therapy has not always remained simple and clear. Moreover, because of the general interest in this method of treatment, more and more companies have increased their activity by supplying instruments and dressings for NPWT. Every company introducing a new product tries to distinguish it from the currently available giving the new term which predisposed to some misunderstandings. Another difficulty is the nomenclature translated from English version to a particular language. Determination to translate the term accurately and unambiguously sometimes may be the source of misunderstanding. Nowadays NWPT is used in many branches of medicine. Routinely, in general surgery but also in non-surgical medical branches, such as cardiology (sternotomy wounds), palliative care (bed sores), dermatology and others. Sometimes it is used by the specialist who does not practice with this method regularly.

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All these aspects mentioned above may be the source of misunderstanding while using NPWT. This work is a kind of synthesis of the basic terminology and principles associated with NPWT. Of course, presented here is only the basic terms with their brief explanations. We presented those key terms used in everyday practice. In the case of highly advanced procedures or related to a particular problem treated with NPWT, some other aspects of this therapy should be considered.

II. SYLLABUS

1. Negative pressure wound therapy (NPWT) and synonyms: Vacuum-assisted closure (VAC), topical negative pressure (TPN), local hypobaric therapy (LHT).

NPWT is an innovative technique of management of chronic and complex wounds using controlled sub-atmospheric pressure. According to the general principles of the method, NPWT consists of several crucial elements (see below). Applied in accordance with generally accepted guidelines, enhances wound healing. Some essential aspects of this method includes; increased blood flow, edema reduction, promotion of granulation and angiogenesis, decreasing of wound size, bacterial load reduction and others greatly contributed to the acceleration of wound healing [2].

Variability of vacuum pump suction settings can be adjusted individually due to the type of wound, location, and other factors. According to guidelines dressings should be changed every 2-3 days [3]. However, because of the high output fistulas, high exudation from the wound or in situations where the system become unsealed, it should be changed more frequently. In the early 1950s the first attempts using vacuum therapy were made. At the beginning there were some technical difficulties associated with keeping the system sealed which is necessary for providing successful therapy. The implementation of Redon drain or using a wall suction source etc. partially solved the problems thus facilitating the usage of the therapy [4,5,6]. The lack of a securely sealed system, source of sub-atmospheric pressure generated, this therapy proved difficult. The presentation by Argenta and Morykwas the first commercially manufactured dressings promptly improved the therapy [7]. Rapidly NPWT has become both widely accepted and popular. Currently NPWT is used in varying branches of medicine. Moreover, in some clinical indications this technique is considered as a method of choice. Continuous improvement in the field of NPWT changed the indications for this technique.

2. Sub-atmospheric/ Negative pressure

The sub-atmospheric pressure is generated within the wound by the vacuum pump. The negative pressure has an influence on the sequence of action underlying this technique, such as blood flow, angiogenesis, granulation, edema reduction and others. Although the research on the impact of negative pressure on the wound healing process are more and more intensified, the optimal negative pressure has been deliberated in recent years [8,9]. Morykwas et al. demonstrated using a sub-atmospheric pressure of 125 mmHg a 4-fold increase in blood flow within the wound, which significantly enhanced the process of wound healing [7]. Wakenfors et al. analyzed the effect of pressure ranging 50-200 mmHg in animal models showing that depending on the tissue type to which the negative pressure was applied, the optimal pressure value is varied depending on the consistency of the tissue [10,11]. They concluded that soft tissue (e.g. dermis) required optimal pressures of 75 mmHg, whereas in the case of more dense type of tissue (e.g. muscle) 100 mmHg seemed optimum.

Based on the current knowledge, it is considered that the optimum pressure should be set individually, not only in terms of the type of wound and its anatomical location, but also according to the other aspects influencing the wound environment [12]. Nevertheless, the usage of negative pressure above 125 mmHg can significantly affects the tissue because of the ischemic processes [10,11].

3. Continuous or intermittent pressure

There are two basic settings of negative pressure. The NPWT allows the setup of either continuous or intermittent negative pressure applied within the wound. The intermittent pressure is characterized by sequential cycles of the pause of action associated with the reduction of the pressure relatively to the active cycle, which is constituted as an overriding pressure generated by the vacuum pump. It is worth noting that by using intermittent pressure, in both cycles the negative pressure is constantly generated with reduced value of the pressure during the pause of action whereas a similar or equal to the optimum pressure is applied during the active cycle.

Both passive and active cycles can be adjusted individually regarding the value of the pressure as well as the time of the cycles (in general the active cycles is longer than the pause cycles). The gold standard of NPWT is based on a 5 minutes long active cycle followed by a 2 minutes cycle of passive cycle [13].

According to the recent research on animal models as well as clinical trials it has been revealed that the therapy based on intermittent pressure led to better results than when using continuous pressure. Morykwas and Argenta proved that by using intermittent pressure higher rates of wound granulation ensued than when using continuous pressure (103 % vs 35.3% ± 63.3 % ± 26.1%, respectively) [7]. It was confirmed that prolonged application of negative pressure (continuous pressure) was associated with ischemic effects due to the excessive blood maintenance in the capillaries [12]. Pause of the action due to intermittent pressure creates favorable conditions for the outflow of residual venous blood and allows the blood to be circulated with oxygenated amount of the blood. However, according to some authors, the intermittent pressure is associated with more discomfort felt by the patients [12]. It is important to note that the choice of both the negative pressure value and the sequences of time selection for the intermittent pressure depends on many factors and should be subjected to a thorough analysis of the optimal settings. Location of the wound, type of the tissue, internal organs or blood vessels exposure should determine the settings of these parameters individually.

4. Foam/ sponge

This is an important component of the NPWT. Due to the micro porous structure of the sponge, the negative pressure within the wound may be regularly distributed throughout the dressing. Currently there are two types of sponges commercially available: polyvinyl - alcohol (PVA) and polyurethane (PU). Foam
based on polyurethane is characterized by high absorption of wound discharge thus the exudate can be easily drained outside the wound, which reduces skin irritation and maceration around the wound. It was confirmed that evacuation of excessive wound fluid poses a positive impact on the osmotic as well as oncotic gradients within the wound thus facilitating wound healing [3]. The mean pore size of polyurethane is around 423 μm. Moreover, this form of the dressing allows the moisture environment of the wound to be maintained. In addition, there is a significant influence on epithelialization with the tendency to the regular organization of the epithelial cells typically found in intact layers of the dermis [14]. Provided by different companies, foams are varied in shape, thickness and dimension, which make them easily adapted to current needs. Hypoallergenic foam properties means that the sensitivity to this material are rare. Plasticity of the foam allows the continuous shrinkage of the foam in three dimensions with subsequent contraction of the wound. Scherer et al. revealed an 80% decrease in volume of the polyurethane foam using sub-atmospheric pressure around 125 mmHg with significantly contraction of the wound [15]. On the other hand, prolonged maintenance of the foam in the wound and rapid stimulation for granulation processes may cause its foam ingrown resulting in bleeding while the dressing is changed.

5. Pad/ port

Primarily some kind of drain was the element making the complex of NPWT integrated, connecting the wound with the vacuum source. However, usually the dressing system remained unsealed. Moreover, the therapy was associated with patient’s discomfort because of the lack of mobility of the vacuum pump. Typically, the pad is manufactured to be firmly connected with the drain. Pads are different in shapes and sizes, with a varying number of channels simplifying the application of NPWT. It is usually in the form of a flat silicon plastic element that does not affect the patients’ mobility and comfort. Moreover, it is characterized by a low failure rate of keeping the system sealed. In general, the drain is composed of several working channels, thus the blockage of one of them, allows the system to keep working without the necessity of changing the whole application. The pad is placed over the foam layer in the central part of the wound at the site of the most intense exudation. In cases of extensive abdominal wounds, complicated with high secretion or in the presence of enterocutaneous fistulas, consideration should be done to apply two or more pads connected with the same vacuum pump. There are available specially designed converters linking the drains to one.

6. Complex wound

Surgical site factors of the complex wound may impair the natural responses of the body to facilitate the regeneration process of the wound. Defining clearly the term complex wound is difficult, and the list of factors affecting appropriate healing is substantial. In contrast to the natural cascade of acute wound healing, in the context of chronic and complicated wounds this kind of sequences either do not appear or are usually disturbed [3]. Trauma, surgical site infection, foreign bodies, hypoxia or comorbidities and others may impair the process of wound healing [12].

Regarding complex wounds using NPWT, typically there are the wounds which are impossible to be secured with a standard dressing. The special indications for using NPWT excepting complex wounds, are the wounds at difficult location to be secured in a typical manner such as a perianal or parastomal region or located nearby to natural cutaneous folds, etc. Another indication is an extensive wound with high exudate or with the presence of fistulas, where the standard wound supply is associated with the necessity for a number of dressing changes per day. NPWT may acts also as a bridging therapy in the case of using skin grafts to facilitate the final outcomes [16,17].

7. Enterocutaneous fistula, enteroatmospheric fistula

According to the fistula definition, there is somehow a connection between two epithelialized surfaces. In the case of enterocutaneous fistula (ECF), there is a communication between intraluminal surface of bowels and the skin [18]. Using NPWT for the purpose of treatment has been deliberated for many years. Primarily the usage of NPWT was contraindicated in the case of ECF [19,]. The first reports using NWPT in the field of open abdomen management caused many objections [20]. Because of the difficulties in securing these kinds of patients commonly associated with both ECF and open abdomen, NPWT was considered as the last chance therapy. Some first breakthrough results brought the acceptance for using this therapy [21,22]. Currently NPWT is used for open abdomen, either as the primary treatment of open abdomen as well as to protect the appearance of iatrogenic fistulas, or as a method of choice in the management of open abdomen associated with ECFs [23]. More and more reports have suggested a significant influence on the course of ECF management with NPWT. In the case of multiple ECFs application NPWT allow us to heal some fistulas, regarding one of them as a “stoma”. This approach may significantly improve the general condition of the patient, reduce the number of ECFs and greatly facilitate the healing of complex abdominal wall defects [24].

8. Open abdomen

This is a surgical management related to the inability of closing the abdominal wall due to some impaired surgical condition such as an abdominal compartment syndrome, necrotizing fasciitis etc., or when immediate and frequent abdominal approach is crucial for the appropriate management with damage-control laparotomy. Among varying techniques used for this purpose such as Bogota bag, zippers, silos, etc., recent studies have demonstrated the high efficiency of using NWPT. Miller et al. demonstrated a high rate of 88% effectiveness of fascial closure in patients with extensive abdominal wound resulting in the fascial closure failure [25]. A specially designed non-adhesive drape has greatly facilitated the management of open abdomen. Arigon et al. presented the excellent outcomes resulting in high recovery rate using NWPT based on the non-adhesive drape in the management of open abdomen [26]. Application of non-adhesive layer directly over exposed intestinal loops significantly reduce the risk of enterocutaneous fistulas development[27,28]. Similarly to other components of the dressing, the non-adhesive drape allows for an appropriate adjustment of the wound size. This part of the dressing should be changed regularly at the same time of entire dressing system.
change. The open abdomen treated with NPWT was characterized by the lower incidence rate of postoperative abdominal hernias [29].

9. Granulation
Complex mechanisms of NPWT for wound healing influence not only the elimination of edema and removal of exudates but also reducing the number of bacteria within the wound and increasing the blood flow in the surrounding capillaries [12]. All of these mechanisms of action impact on the process of re-epithelialization. Due to the increased migration of inflammatory cells and fibroblasts, the process of wound granulation occurs faster. Fabian et al. demonstrated a statistically significant difference in the granulation using NPWT on animal models in contrast to standard dressings [30]. Similar results were presented by Morykwas et al. [31]. In the popcorn model they proved increased granulation of the wound bed using NPWT. Moreover their analysis regarding applied negative pressure value within the wound demonstrated that the optimum pressure for the granulation process is 125 mmHg. Labler et al. measured profiles of cytokines collected from both wound discharge and serum in patients treated with NPWT [32]. They revealed elevated cytokine levels predisposing to neovascularization and thus promoting granulation. Joseph et al. showed a statistically significant reduction in depth and width of the wound using NPWT in contrast to the wound supplied in a conventional manner [33].

10. Vacuum pump
This is a key element of the therapy. The vacuum pump is responsible for constantly supplying and maintaining the negative pressure within the entire wound. Simple form of the screen display for both patients and medical personnel gives the information about the parameters needed to be changed as well as technical failures in an understandable way. Miniaturization of the equipment makes NPWT units more and more simple and smart. Built-in wireless power enables patient’s to be transported without the need of interrupting therapy. Vacuum pump is lightweight, portable and easy to deal with. Moreover more companies manufactured vacuum pumps for outpatient therapy.

11. Adhesive drape
It is a transparent adhesive drape applied as the final element of the dressing. Adhesive drapes are the component keeping the entire system sealed and thus maintaining the sub-atmospheric pressure inside the wound. Varying in shape and dimensions but also with the possibility of cutting to the appropriate sizes make this step of application simple to perform. The application of the drape should not only cover the previously applied layers of the dressing but overlapping the area of healthy part of the skin adjusted to the wound forming together an integral part of the dressing. From a practical point of view, it is important to prepare the skin surrounding the wound, e.g. remove hair from the regions of its application and to ensure that the skin is dry prior to application. Hence this creates favorable conditions for application but also for its subsequent removal without any discomfort to patients. Usually this drape does not result in the development any allergic reactions.

12. Non-adhesive drape (intraabdominal dressing)
A component of NPWT in the management of open abdomen. The non-adhesive drape allows the safe application of NPWT over the exposed bowels’ loops. The drape forms a kind of barrier between the foam and the intestines, effectively separating the abdominal organs and dressing layers thus reducing the risk of iatrogenic injury to intrabdominal organs. Technical aspects such as drape’s pockets facilitated an optimal distribution of non-adhesive drape. Simplicity of drape cutting and elasticity allows the application to be easy in otherwise difficult abdominal regions.

The introduction non-adhesive drape significantly improve long-term outcomes in the group of patients with open abdomen treated with NPWT. Although as a generally accepted method, for the purpose of open abdomen, it was initially looked at as a controversial method. However, according to recent studies, the method was confirmed to be feasible, successful and safe [23]. Based on reports regarding open abdomen therapy treated with NPWT complicated with the formation of intestinal fistulas, some objections were postulated [20,34]. The introduction non-adhesive drape for the open abdomen management has resulted in the decreasing incidence of new enterocutaneous fistulas formation [35,36].

13. Exudate canister
Replaceable element of NPWT. This is some kind of container where wound discharge is drained and collected directly from the wound. Depending on the company producing the dressings, the canister varies in volume. Moreover, for outpatient therapy, canisters are smart and easy to be changed by non-medical personnel. From the practical point of view, the vacuum pump is programmed to give a message at the time of complete filling and need for replacement.

14. Debridement
Regardless the type of wound and its location, the essential element necessary for the appropriate wound healing processes is the debridement. Elimination of toxic factors, both physical and biological remains a crucial step in the conditioning of wound healing.

A typical feature of chronic wounds is the formation of a fibrin layer on their surfaces, which effectively reduces the inflow of valuable cell enhancing regeneration and granulation. Such conditions predisposes to colonization by microorganisms with further complications.

Surgical is the most common form of wound debridement. Removal of necrotic tissue and fibrin refreshing the wound edges and are the key elements of traditional debridement. Debridement of necrotic tissue eliminates cells which potentially may be a source of endotoxins [12]. Moreover, inflammatory processes within the wound may impair the natural mechanisms of granulation by deactivated tissue growth factors [12].

15. Stoma
The stoma appliances play an important role in the care of patients treated with NWPT. Both stoma bags and stoma paste were found as an important elements supporting therapy using sub-atmospheric pressure. Stoma bags serve as a container for highly exudative wounds as well as for enterocutaneous fistulas.
III. CONCLUSIONS

Multidirectional intensive developments of NPWT is associated with further innovation in the field of wound healing. The continuous introduction of new products of NPWT makes the final form of the therapy unpredictable. Intense miniaturization, reliability and simplicity, makes this technique widely available and easy to perform. Introduction of this therapy to many branches of medicine, requires the basal knowledge about this therapy for medical personnel regardless of the medical specialization.

The further evolution of vacuum therapy and subsequent technical facilities are possibly associated with the implementation of new definitions and terminology associated with NPWT in the near future.

We believe that this study makes the basic knowledge about NPWT easier to understand for both medical practitioners and medical adepts.

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