

Cost analysis of Topical Negative Pressure (TNP) Therapy for traumatic acquired wounds

Kostenanalyse der Vakuumtherapie für traumatische Weichteildefekte

Abstract

Extended traumatic wounds require extended reconstructive operations and are accompanied by long hospitalizations and risks of infection, thrombosis and flap loss. In particular, the frequently used Topical Negative Pressure (TNP) Therapy is regarded as cost-intensive. The costs of TNP in the context of traumatic wounds is analyzed using the method of health economic evaluation.

All patients (n=67: 45 male, 22 female; average age 54 y) with traumatically acquired wounds being treated with TNP at the university hospital of Goettingen in the period 01/01/2005–31/12/2007 comprise the basis for this analysis. The concept of activity-based costing based on clinical pathways according to InEK (National Institute for the Hospital Remuneration System) systematic calculations was chosen for cost accounting. In addition, a special module system adaptable for individual courses of disease was developed.

The treated wounds were located on a lower extremity in 83.7% of cases (n=56) and on an upper extremity in 16.3% of cases (n=11). The average time of hospitalization of the patients was 54 days. Twenty-five patients (37.31%) exceeded the „maximum length of stay“ of their associated DRG (Diagnosis Related Groups). The total PCCL (patient clinical complexity level = patient severity score) of 2.99 reflects the seriousness of disease. For the treatment of the 67 patients, total costs were \$1,729,922.32 (1,249,176.91 €). The cost calculation showed a financial deficit of \$-210,932.50 (-152,314.36 €). Within the entire treatment costs of \$218,848.07 (158,030.19 €), 12.65% per case were created by TNP with material costs of \$102,528.74 (74,036 €), representing 5.92% of entire costs. The cost of TNP per patient averaged \$3,266.39 (2,358.66 €).

The main portion of the costs was not – as is often expected – due to high material costs of TNP but instead to long-term treatments. Because of their complexity, the cases are insufficiently represented in the lump-sum calculation of the InEK. A differentiated integration of complex TNP-treatment in the DRG system (e.g., as an expanded DRG I98Z) would be a step towards cost recovery. In addition, the refunding of outpatient TNP-treatment would lead to enhanced quality of life for the patients and to a reduction of hospital costs and length of stay.

Keywords: topical negative pressure therapy (TNP), traumatic wound, economic evaluation, cost analysis, vacuum assisted closure (VAC)

Zusammenfassung

Ausgedehnte traumatische Weichteildefekte erfordern aufwändige rekonstruktive Operationsverfahren und sind von langen Liegezeiten und Risiken wie Infektion, Thrombose und Lappenverlusten gekennzeichnet. Die Vakuumtherapie (VAC) stellt dabei eine wesentliche und häufig angewandte Therapie dar, die als kostenintensiv angesehen wird. Die Kosten dieser Vakuumtherapie in der Behandlung des traumatischen

Leila Kolios¹
 Georg Kolios²
 Marius Beyersdorff³
 Clemens Dumont¹
 Jan Stromps²
 Sebastian Freytag⁴
 Klaus Stuermer¹

1 Department of Trauma Surgery, Plastic and Reconstructive Surgery, University of Goettingen, Germany

2 Department of Plastic, Reconstructive and Aesthetic Surgery, Klinikum Bremen-Mitte gGmbH, Bremen, Germany

3 Department of Economy & LAW, University of Applied Sciences, Rheinische Fachhochschule Köln, Germany

4 Staff Department of Central Controlling, University of Goettingen, Germany

Weichteildefekts werden in der vorliegenden Arbeit mit der Methodik der gesundheitsökonomischen Evaluation analysiert.

Alle Patienten (n=67; 45 m, 22 w; Ø 54 J.) mit traumatischem Weichteildefekt, die zwischen 01/01/2005–31/12/2007 an der Universitätsklinik Göttingen mit VAC behandelt wurden, wurden in die Evaluation eingeschlossen. Die Methode der Prozesskostenrechnung anhand Klinischer Pfade, welche sich an der InEK (Institut für das Entgeltsystem im Krankenhaus)-Systematik orientiert, war Grundlage dieser Kalkulation. Zusätzlich wurde ein neues Modulsystem entwickelt, welches es ermöglichte, individuelle Patientenkarrieren exakt abzubilden.

Die behandelten Weichteildefekte waren in 83,7% der Fälle (n=56) an der oberen Extremität und in 16,3% der Fälle (n=11) an der unteren Extremität lokalisiert. Die durchschnittliche Liegezeit betrug 54 Tage. 25 Patienten (37,31%) überschritten die obere Grenzverweildauer ihrer assoziierten DRG (Diagnosebezogene Fallgruppen). Der PCCL (patientenbezogener Gesamtschweregrad)-Wert von 2,99 zeigt den hohen Schweregrad dieses Kollektivs an. Für die Behandlung dieser 67 Patienten entstanden Kosten von 1.249.176,91 €. Die Kosten-Erlöskalkulation zeigte eine Negativbilanz von –152.314,36 €. Die Kosten für die VAC Behandlung betrugen 158.030,19 € (12,65%) mit Materialkostenanteil von 5,92% (74.036 €). Die Gesamtkosten pro Patient für die VAC Therapie betragen 2.358,66 €.

Der Hauptanteil der entstehenden Behandlungskosten bestand nicht, wie häufig angenommen, aus den Materialkosten für die VAC Behandlung, sondern in den langen Liegezeiten dieser Patienten. Aufgrund ihrer Komplexität sind diese Fälle nicht adäquat in der Fallpauschalenkalkulation des InEK abgebildet. Eine differenzierte Integration der komplexen Vakuumbehandlung in das DRG-System (z.B. als erweiterte DRG I98Z) würde die Erlössituation sachgerechter abbilden. Auch die Erstattung ambulanter VAC Therapie würde, neben erhöhter Lebensqualität für die Patienten, die Behandlungskosten und stationären Liegezeiten reduzieren.

Schlüsselwörter: Vakuumtherapie (VAC), traumatischer Weichteildefekt, ökonomische Evaluation, Kostenanalyse

Introduction

Large traumatic wounds are frequent and cost-intensive problems in the treatment of severely injured patients. They require extended reconstructive operations and are accompanied by long hospitalizations and risks of infection, thrombosis and flap-loss [1]. The topical negative pressure (TNP) therapy provides a paradigm that can be used in concert with a wide variety of standard existing plastic surgery techniques [2]. It is one of the essential methods in treatment of these wounds and has become an integral part of the clinical routine [3]. Fleischmann et al. [4] were the first to describe the treatment of acute soft tissue trauma (primarily combined with open fractures) with TNP.

There is a need for more economic analysis research in plastic surgery studies [5]. The cost-effectiveness of TNP has been evaluated in four large studies in the USA [6], [7], [8] and the Netherlands [9], but all of them evaluated chronic wounds. Until now, no economic evaluations of treatment of traumatic wounds with TNP exist. Nord et al. [10] describe TNP as one of the most cost-effective methods for wound treatment. The high material costs

of TNP may be balanced by reduced nursing-costs and reduced hospitalization-time for the patients [11]. The morbidity and mortality after postoperative infections of the sternum is reduced with TNP [12].

Since 2004 coding of TNP in the German DRG accounting system is possible with the new OPS (German Procedure Classification)-Code 5-916.a [13]. To reflect the complexity of TNP especially in the treatment of musculoskeletal trauma the DRG I98Z was established in 2007. Until now, it has been unclear whether the existing proceeding calculation of the InEK (National Institute for the Hospital Remuneration System) covers the actual costs of TNP for traumatic wounds.

Economic evaluation is a way of assessing medical procedures [14]. The aim is to obtain objective information allowing for a transparent estimation of costs associated with a medical measure [15]. This process facilitates decisions about allocation of resources, regulation or development processes [16]. Dependent on the perspective, different study profiles can be used: non-comparative-studies (like “cost-analysis” or “disease-cost-analysis”) or comparative studies like “cost-benefit-analysis” or “cost-effective-analysis” [14]. The approval used in eval-

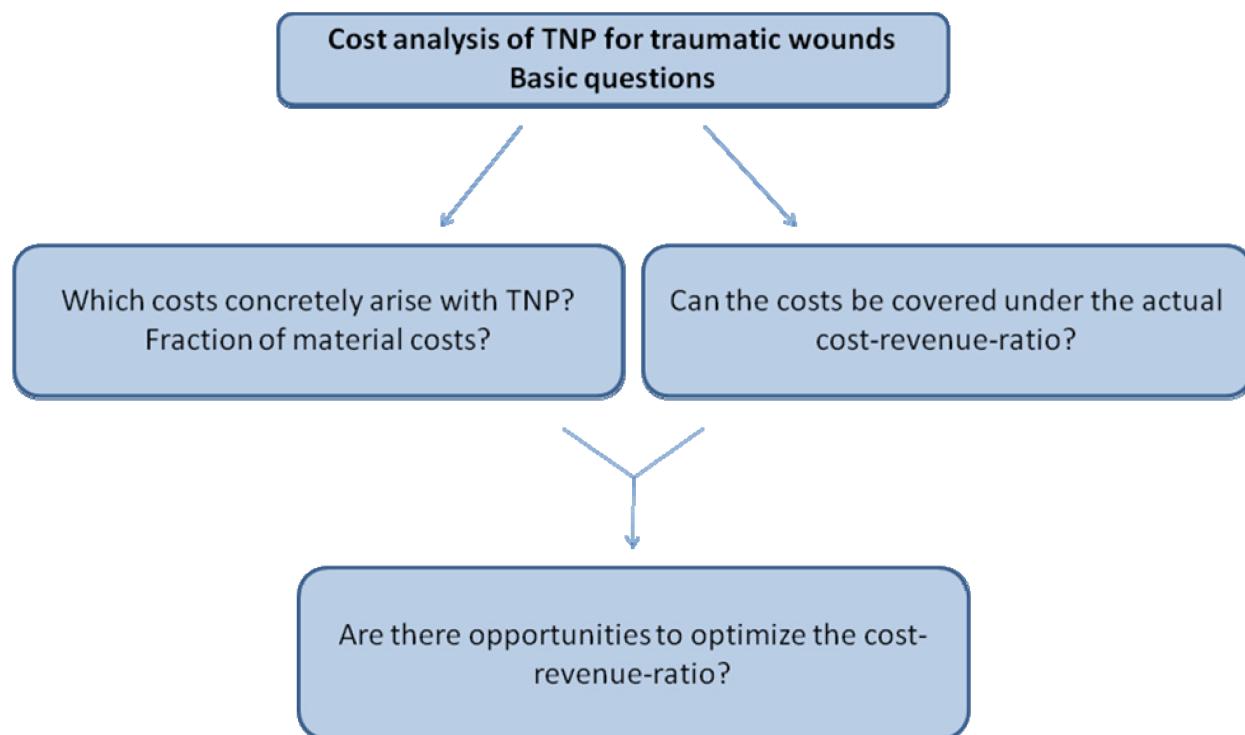


Figure 1: Diagram of the “Basic Questions” being the main focus of this evaluation

uation studies is defined by the “Hannoveraner Konsens” [15]. In our study, we used the “cost-analysis” study profile measuring the concrete costs of a procedure as activity-based costing based on clinical pathways [14]. The following questions form the basis of this evaluation (Figure 1):

1. Which costs for the hospital are associated with using TNP treatment for traumatic acquired wounds? Are the material costs of TNP the main component?
2. Can the cost of inpatient treatment of patients with traumatic wounds be covered under the actual cost revenue ratio (considering “best-case” and “worst-case”-scenario)?
3. If necessary, are there opportunities to reduce the costs related to TNP-therapy for traumatic wounds?

Methods

All patients (n=67: 45 male, 22 female; average age 54 y) with traumatically acquired wounds being treated with TNP in the period from 01/01/2005–31/12/2007 in the Department of Trauma Surgery, University Medicine of Goettingen, were included in this analysis. The wounds were separated into *primary* tissue defects (including open fractures, decollements, burns, and direct tissue trauma) and *secondary* tissue defects (including compartment syndrome, hematomas, infections, and necroses). Inclusion criteria were the operation/procedure-keys which can be clearly related to TNP-therapy (application or change of TNP systems) (OPS 5-916.a0 and 5-916.a1). Excluded from the study were all patients with chronically tissue defects, multiple trauma patients (due to their high

number of concomitant diseases and injuries) and all patients grouped in an “artificial respiration DRG” based on long term artificial respiration.

A model for the calculation of treatment costs was developed. Close relation to the treatment processes, calculation according to the InEK calculation systems and adaptability to other groups of disease were the requirements for this model. An activity-based costing approach based on clinical pathways was chosen for an appropriate cost accounting.

Activity-based costing allocates the individual- and overhead-costs to processes. All treatment activities were described and evaluated in process-modules (e.g., ward rounds, blood collection, documentation). Modules belonging together were combined to process-blocks (e.g. emergency room, operation, ward) (Table 1). The process-blocks together represent the overall process. Due to the heterogeneity of cases, the sequence of the process-blocks was adapted individually to each patient.

The combination of the process-blocks in relation to the individual patient carriers (dependent on length of hospitalization, amount of operations or complications) represents the *clinical pathway*. Non-patient-related overall costs (personnel and material costs of medical and non-medical infrastructure) were not represented; they were allocated using percentages as *overhead costs* for each case. The clinical pathway allowed the identification of real costs arising from TNP. The cost categories were chosen according to the InEK-calculation-compendium to rise comparability of measurement [17].

The *physician-related activity* was calculated with working-minutes for every process-modules and -blocks (Table 2). For the process-block “operation” the working-minutes

Table 2: Calculation physician-related activity (ward and OP)

The costs of physician-related activity on the ward are calculated by multiplication of occurred process blocks during therapy with cost/working minute. For calculating costs of the operations, working minutes of surgeons (incl. bedding of patients, documentation time) and anesthesists (considering premedication, recovery room) are combined. Origin: own construction.

Calculation physician-related activity (ward)	
activity	physician efforts
costs	number of process blocks during therapy costs per minute
basis of calculation	= number of process-blocks during therapy * costs / minute
Calculation physician-related activity (OP)	
activity	physician efforts OP / anesthesia \sum surgeon presence time / \sum cut-to-suture time + anesth.time x number of OPs + premedication x number of OPs + post-OP recovery room x number of OPs
costs	costs per minute
basis of calculation	= \sum surgeon presence time * costs per minute / \sum cut-to-suture time + anesth. time x number of OPs + premedication x number of OPs + post-OP recovery room x number of Ops * costs per minute

Table 3: Nursing-related activity; the LEP-variable groups

The nursing-related activity was collected by the LEP (detection of nursing activity) system. It is based on the daily documentation of patient-related care variables and nursing efforts in a special software program. Origin: own construction.

Master data	
1 master data (taken from administrative system)	
Patient-related informations	
11	condition variables
18/19	specific condition variables
21	additional information
22	additional information – nursing Intensive Care Unit
28/29	additional information - hospital specific
Nursing variables	
31	movement
32	pers. hygiene/clothing
33	eating/drinking
34	excretion
35	breathing/circulation
41	documentation/administration
42	interview
43	activity
44	attendance/support
45	security
46	hygiene
51	meeting/organization
52	laboratory sample
53	medication
54	treatment

were not standardized due to the individuality of the activity. Therefore, the summarized "surgeon-presence-time"/"cut-to-suture time"/"anesthesia-time" and the blocks "pre-medication"/"post-op-recovery-room-time" was calculated (Table 2).

The *nursing-related activity* was collected by the LEP (detection of nursing activity) system. It is based on daily documentation of patient-related care variables and nursing efforts in a special software program (Table 3). The activity of other functions and medical-technical service (physiotherapists, patient transport service) were included into overhead costs. The *material costs* were calculated separately; costs of pharmaceuticals and general medical treatment were calculated according to the InEK calculation-system: overall costs were divided

by the LEP-hours to obtain a cost rate per LEP-hour. The costs of the implants (osteosynthesis material) were individually attached to patients from the OP-information system and costs were generated from purchasing department. Material costs of the TNP-system were calculated by multiplication of the day rate of TNP-therapy (66.40 €/d for providing of the pump system and the dressing materials) with the length of treatment. After calculation of cost categories, they were assigned to their particular cost unit (e.g. ward, anesthesia, radiology) according to the InEK calculation-system. To compare the expenses incurred with the incoming revenue obtained from a funding agency a calculation of cost per unit was performed. Six patients were chosen as example cases and their costs were calculated. Be-

cause of the close relationship of cost to the length of hospitalization, one patient each was chosen with long, medium and short hospital stays for primary and for secondary tissue defect examples (P1, P2, P3, S1, S2, S3).

Again, costs for *physician-related activity* were evaluated by working minutes, multiplied by the base rate of pre-tax personnel costs, working hours per month and a 15% deduction for absences from work. In this way, costs for an assistant physician of 0.68 €/min, for a consultant physician of 0.86 €/min and for a deputy physician of 0.95 €/min were calculated. The calculation of the *nursing-related costs* was based on LEP system. For calculation of the cost-group medical-technical service the working minutes of the pathway were multiplied by the costs/min, resulting in 0.4 €/min, respectively 1.16 €/min for the operation-related service. *Material costs* were either related to the LEP-hours (general medical demand) or calculated individually (expensive implant and TNP costs). Overhead costs for medical and non-medical infrastructure for the Department of Trauma Surgery, Plastic and Reconstructive Surgery were calculated from the University Staff Department of Central Controlling with 32–35% of total costs, due to high contingency costs for resuscitation rooms, emergency operations and intermediate care ward. They were calculated as percentage additional charge per cost unit multiplied by the cumulated personnel- and material costs (Table 4, last column, Table 5).

In addition, costs were referred and analyzed according to the DRG earnings. The DRG-system of the year 2007 was used. All cases of 2005 and 2006 were newly grouped using the 2007 system because the DRG I98Z (complex negative pressure therapy of diseases and disruption of musculoskeletal system and connective tissue) was not established prior to 2007.

To confirm robustness of data a sensitivity-analysis was performed. Judgmental parameters were varied to represent the heterogeneity of the cases. In a “best-case” and “worst-case” analysis the parameters “base-case-value” for the funding agency and “pathway-minutes” for the supplier were reviewed in order to determine their sensitivity.

A summary of the calculation system is given in Table 4. The study was certified by our institutional ethics committee (AZ 13/3/08).

Results

In the period from 01/01/2005–31/12/2007, 67 patients with traumatically acquired wounds were treated with TNP (OPS 5-916.a0 and 5-916.a1). In 30 cases (44.8%) primary tissue defects were treated with TNP. The predominant diagnosis was open fracture with 30% (n=20) of all defects. Thirty-seven patients (55.2%) had secondary tissue defects (including compartment syndrome, hematomas, infections and necroses). In this group, secondary infections were the largest part due to

the extended and highly contaminated wounds, making up 34.3% (n=23). The hospitalization time of patients with primary tissue defects ranged from 15 d (P3) to 128 d (P1) with a mean of 39.5 d (P2). With secondary tissue defects patients stayed from 14 d (S3) to 98 d (S1) with a mean of 38 d (S2). A total of 37.31% of the patients (n=25) stayed longer than the “upper residence time”. No patient was released from the hospital prior to the “lowest residence time”, and 28.36% (n=19) were released before reaching the “middle residence time”. The evaluated cases had a PCCL (describes a patient severity score in four steps from undemanding (PCCL 0) to complex, severe (PCCL 4) diseases and treatments) of 2.99, reflecting the complex and severe nature of the cases. To answer the questions posed in the introduction (Figure 1), the following results can be presented (question 3 will be answered in the Discussion):

1. During the overall treatment, the aggregated costs for the TNP-treatment were 158,030.19 €. This makes up 12.65% of the overall costs of 1,249,227.52 € for complete inpatient therapy. 74,036 € of TNP related costs were generated by material costs (5.93% of the overall costs) and 83,994.19 € were generated by personnel and operation related material costs on ward and in operating theater (Table 6).
2. The analysis shows the actual cost of 1,249,227.52 € for the treatment of traumatic tissue defects are reimbursed with 1,096,913.16 €. A negative cost-revenue ratio of -152,314.36 € remains, of which 86.23% is allotted to patients with primary tissue defects. The personnel costs of physician, nursing and medical-technical services makes up 49.75% of the overall costs, while 17.04% is made up by material costs. The remaining costs can be attributed to personnel and material costs of medical and non-medical infrastructure with 31.60% of overall costs (220,072.94 €) for the collective of patients with primary tissue defects and 35.23% of overall cost (194,738.55 €) for the collective of patients with secondary tissue defects (Table 6). Table 5 presents the calculation of overhead costs related to the different length of hospital stay.

Performing the sensitivity analysis from the perspective of the funding agency with varying “base-case-values”, an overall cost of 993,114.2 € arises for the “best-case-scenario” of TNP treated traumatic tissue defects. In calculating “worst-case-scenario”, the overall costs are 1,096,698.23 €. Thus, costs for the funding agency vary by an absolute 106,177.99 €. The sensitivity analysis from the point of view of the supplier depends on diverging “pathway-minutes”. The variation intervals for the pathway-minutes were calculated using a variation coefficient. For the supplier (hospital) the overall costs can be reduced by 87,829.83 € total or 1,310.89 € per case for the “best-case-scenario”. For the “worst-case-scenario” the overall costs increase by about 81,330.59 € total/1,213.89 € per case.

Table 4: Summary of the established calculation system
 Origin: own construction.

Calculation TNP-patients		Personnel costs physician	Personnel costs nursing	Personnel costs med.-techn. service/function-service	Material costs pharmaceuticals	Material costs implants/transplants	Material costs further medical demand	Personnel and material costs further med. & non med. infrastructure
1	2	3	4a	4b	5	6a	6b	7&8
Normal ward	1	minutes out of pathway	LEP-registration	minutes out of pathway	LEP-hours	Blood substitute single entry	LEP-hours	OC 1- 6b * % CUG 1
Intensive Care	2	minutes out of pathway	LEP-registration	minutes out of pathway	LEP-hours		not relevant	OC 1- 6b * % CUG 2
OP theater	4	SPB – SPE with SF	CST + anesthesia time + premedication + post-OP recovery room	CST + setup-time	CST + setup-time	Assignment individual costs	CST	OC 1- 6b * % CUG 4
Anesthesia	5	not relevant		CST + setup-time	Anesthesia time	not relevant	not relevant	OC 1- 6b * % CUG 5
Cardiology diagnostics/therapy	7	Values from DRG-Browser	Values from DRG- Browser	Values from DRG- Browser	Values from DRG- Browser	Values from DRG- Browser	Values from DRG- Browser	Values from DRG- Browser
Endoscopy diagnostics/therapy	8	Values from DRG-Browser	Values DRG- Browser	Values from DRG- Browser	Values from DRG- Browser	Values from DRG- Browser	Values from DRG- Browser	Values from DRG- Browser
Radiology	9	Points out of CB * % PRA		Points out of CB * % FS		Points out of CB * % Inf.		Points out of CB * % Inf.
Laboratories	10	Points out of CB * % PRA	not relevant	Points out of CB * % FS		Points out of CB * % MC		Points out of CB * % Inf.
Further diagnostic & therapeutic areas	11	Points out of CB * % PRA		Points out of CB * % FS		Points out of CB * % MC		Points out of CB * % Inf.

Abbrev.: SPB - surgeon presence begin, SPE - surgeon presence end, SF - simultaneity factor, CST - cut-to-suture time, CB - catalogue of benefits, PRA - physician-related activity, FSFS - function service, MC - material costs, CUUG - cost unit groups, OC - overall costs, Inf. - infrastructure

Table 5: Example calculation of overhead costs

Overhead costs are shown itemized for patients with different lengths of stay (P1–S3) and related to the particular cost units (CU). Overall overhead costs are presented in Table 7. (CC=cost categories, P1–3 = patients with primary tissue defects, S1–3 = patients with secondary tissue defects). Origin: own construction.

Cost Unit	Calculation factor	P1	P2	P3	S1	S2	S3
Normal ward (CU1)	= Σ CC * % (€) Infrastructure	9,930.1	3,445.0	276.85	8,377.9	3,673.2	1,375.9
Intensiv-Care (CU2)	= Σ CC * % (€) Infrastructure	2,832.3	0	925.5	189.0	21.6	0
OP (CU4)	= Σ CC * % (€) Infrastructure	2,888.5	796.6	1,160.4	1,414.8	1,045.0	335.5
Anaesthesia (CU5)	= Σ CC * % (€) Infrastructure	519.8	79.2	181.4	276.9	186.7	83.5

Thus, the funding situation for the hospital even in the “best-case-scenario” is not covering the cost of treatment. The loss amounts for the best-case-scenario to 962.46 € per case and to 3.490.45 € per case for the worst-scenario.

The DRG-related cost analysis is presented in Table 7; in Table 8 the cost-revenue ratio is shown and Table 6 presents the summarized results of the cost analysis.

Discussion

In trauma patients, primary and secondary tissue defects often require long duration of treatment. For therapy of these traumatic wounds, TNP-therapy represents an essential and frequently used technique [3]. The high cost of medical care has come under scrutiny by payers and physicians [18] and since the introduction of the DRG I98Z in 2007 it remains unclear whether treatment with TNP for traumatic wounds can be done in a cost-covering fashion.

For the patient collective of this study all trauma patients were chosen for which TNP therapy presents, next to their osteosynthesis, a main part of their therapy. Patients grouped in a “multiple trauma DRG” and “artificial respiration DRG” were not included in the study, because TNP therapy and its costs play only a minor role and reimbursement of such cases is calculated differently. In addition, patients with chronic defects were also excluded due to their high number of concomitant diseases.

- Using methods of cost analysis, an economic evaluation of this topic has been performed. For patients with primary tissue defects the average cost was 8,279.53 € more per case than for patients with secondary tissue defects. This additional charge results from higher material costs (absolute + 16,055.78 €), increased number of operations (on average + 2.7 operations) as well as from elevated number of long-term hospitalization (+ 4.86% compared to patients with secondary defects). The TNP-treatment costs of 158,030.19 € (12.65% of overall costs) were not as high as expected, however TNP changing was done for the main part in operation

theater. Especially TNP related material costs are often assumed to present the main fraction of TNP-therapy, but the arising 74,036 € (5.93% of the overall costs) can alleviate this assumption.

- In contrast, costs for the funding agency (health insurance companies) amounted to 1,096,913.16 € leading to a financial loss of –152,314.36 €, 86.23% of which was attributable to the treatment of primary tissue defects. In cases of secondary tissue defects the revenues led nearly to a cost-covering situation; there the financial loss amounts only –20,979.22 €. We are aware that the DRG system does not allow for total cost coverage for every DRG. However, the negative cost-revenue ratio of –18.86% in cases of primary defects can hardly be compensated by DRGs with a positive ratio.
- Based on these results, some strategic consequences can be considered.

First, structural changes were performed to ensure the efficiency: material resources were concentrated on few storerooms to reduce the part of material not-used and out of date. Thus, costs have already been reduced by about 90,000 € in 2007. Due to new contracts on the part of the procurement department in 2006, another 15% of material costs could have been saved. *The assumed high material costs in the context of treatment with TNP often present the decision criterion for the supplier. However, the presented analysis showed that material costs of TNP were only a relatively small portion, making up 5.93% of total costs. A savings opportunity should be to implement a standardized approach for treatment with TNP. Trueman et al. [11] already showed a significant reduction in hospitalization time with a standardization of TNP-therapy. But until now, there exist no standardized guidelines for the use of TNP therapy [4], [19].

Another opportunity could be the optimization of coding procedures, but due to the presence of a controlling specialist there are no deficits in this aspect in our clinic.

Table 6: Summary of the presentation of the results of cost-analysis
 (including prevalent DRG, differentiated hospitalization time, overall costs and revenues, differentiated costs with special focus on TNP costs and overhead costs). Origin: own construction.

Parameters	Collective total		Collective Primary defect		Collective secondary defect	
Number of cases	67		30		37	
Prevalent DRG grouping (nr.)	I98Z (n=25)		I02 (n=10)		I98Z (n=16)	
Mean age	54		51		56	
Mean hospitalization time	45.3		47		44	
Mean number of operations	5.9		7.4		4.7	
Mean PCCL	2.99		2.8		3.14	
%-long-term patients	37.31		40		35.14	
%-short-term patients	0		0		0	
%-res. time > mid. res. time < sup. res. time	34.33		26.66		40.54	
%-res. time > low. res. time < mid. res. time	28.36		33.34		24.32	
Overall costs	1,249,227.52 €		696,524.04 €		552,703.78 €	
Overall revenues	1,096,913.16 €		565,188.60 €		531,724.56 €	
Cost-Revenue ratio	- 152,314.36 €		- 131,335.44 €		- 20,979.22 €	
Fraction pers. costs (phys.) (in %)	256,011.11 €	20.49%	152,125.00 €	21.83%	103,886.11 €	18.80%
Fraction pers. costs (nurs.) (in %)	251,514.40 €	20.13%	135,203.78 €	19.41%	116,310.61 €	21.04%
Fraction pers. costs (med.-tech.serv.) (in %)	113,991.95 €	9.13%	65,192.01 €	9.36%	48,799.95 €	8.83%
Fraction pharmaceuticals (in %)	86,876.31 €	6.95%	51,131.29 €	7.34%	35,745.15 €	6.47%
Fraction material costs (in %)	51,986.26 €	4.16%	34,021.02 €	4.88%	17,965.24 €	3.25%
Fraction TNP hiring (in %)	74,036.00 €	5.93%	38,778.00 €	5.57%	35,258.00 €	6.38%
Fraction TNP hiring + costs OP for TNP application (in %)	158,030.19 €	12.65%	92,290.43 €	13.25%	65,739.76 €	11.89%
Fraction infrastructure (in %)	414,811.50 €	33.21%	220,072.94 €	31.60%	194,738.55 €	35.23%

Table 7: Cost-analysis DRG-related (NC = number of cases)

Accumulated mean-calculation based on the DRG grouping systematics 2007. Origin: own construction.

DRG	NC primary defects	Mean of DRG- costs per case (primary defects)	NC secondary defects	Mean of DRG- costs per case (secondary defects)	NC	Overall costs
I02A	10	30,205.04 €	1	31,128.64 €	11	30,289.00 €
I02B	1	8,887.92 €	2	9,227.75 €	3	9,114.47 €
I02C	1	13,806.09 €	2	8,685.06 €	3	10,392.07 €
I22A	1	22,542.60 €	-	-	1	22,542.60 €
I22B	1	10,407.38 €	1	8,126.58 €	2	9,266.98 €
I98Z	9	21,780.30 €	16	17,667.43 €	25	19,148.06 €
J02B	-	-	1	5,842.30 €	1	5,842.30 €
J04A	-	-	1	11,117.76 €	1	11,117.76 €
J08B	-	-	1	18,365.76 €	1	18,365.76 €
J21Z	1	18,625.25 €	1	6,013.40 €	2	12,319.33 €
Q02C	-	-	1	11,047.19 €	1	11,047.19 €
T01A	-	-	1	23,336.45 €	1	23,336.45 €
T01C	-	-	4	11,463.43 €	4	11,463.43 €
X01A	1	26,746.02 €	3	13,798.17 €	4	17,035.13 €
X01B	3	10,975.78 €	2	15,986.40 €	5	12,980.03 €
Y01A	2	32,254.17 €	-	-	2	32,254.17 €
Overall cases	30	23,217.47 €	37	14,937.94 €	67	18,645.19 €

Table 8: Cost-revenue ratio

The column "real revenues" contains the revenues of the years 2005, 2006 and 2007. Due to the introduction of the DRG I98Z in 2007, the revenue calculations were additionally adjusted for this year, shown in the last two columns. Origin: own construction.

DRG	Complete Costs	Real revenues	Difference	Revenues 2007	Difference 2007
I02A	30,289.00 €	23,996.46 €	-6,292.54 €	26,112.74 €	-4,176.26 €
I02B	9,114.47 €	15,039.48 €	5,925.01 €	14,534.14 €	5,419.67 €
I02C	10,392.07 €	10,520.72 €	128.65 €	11,144.81 €	752.74 €
I22A	22,542.60 €	11,415.32 €	-11,127.28 €	12,521.27 €	-10,021.33 €
I22B	9,266.98 €	8,574.74 €	-692.24 €	7,293.71 €	-1,973.27 €
I98Z	19,148.06 €	15,185.28 €	-3,962.78 €	18,931.68 €	-216.38 €
J02B	5,842.30 €	7,715.13 €	1,872.83 €	6,346.48 €	504.18 €
J04A	11,117.76 €	7,204.25 €	-3,913.51 €	6,962.18 €	-4,155.58 €
J08B	18,365.76 €	7,303.23 €	-11,062.53 €	6,698.73 €	-11,667.03 €
J21Z	12,319.33 €	7,834.19 €	-4,485.14 €	3,859.98 €	-8,459.35 €
Q02C	11,047.19 €	7,661.26 €	-3,385.93 €	7,480.20 €	-3,566.99 €
T01A	23,336.45 €	35,895.52 €	12,559.07 €	34,689.53 €	11,353.08 €
T01C	11,463.43 €	6,140.61 €	-5,322.82 €	5,597.57 €	-5,865.86 €
X01A	17,035.13 €	9,000.31 €	-8,034.82 €	10,606.07 €	-6,429.06 €
X01B	12,980.03 €	7,770.52 €	-5,209.51 €	6,850.29 €	-6,129.74 €
Y02A	32,254.17 €	32,736.02 €	481.85 €	31,636.18 €	-617.99 €
overall	1,249,227.52 €	995,174.47 €	-254,053.05 €	1,096,913.16 €	-152,314.36 €
Per case	18,645.19 €	14,853.35 €	-3,791.84 €	16,371.84 €	-2,273.35 €

From the economic point of view an adaptation of the product-portfolio of the corporation (hospital) would be an important step to remain capable of acting and competing. However, for a tertiary care hospital of maximal treatment such adaptations are not possible because it has to provide all diagnostic and therapeutic possibilities. In addition, the number of complex medical cases with severe diseases in a university hospital is elevated, which reduces the possibilities of cost-optimization and benchmarking [20]. A large amount of the evaluated cases is not represented by calculation of case-based lump sum of the InEK. The reason could be the activity profile of the 249 participating hospitals. A strategy for improvement would be the participation of many tertiary care hospitals in calculations of the InEK. Furthermore, complex cases could be represented in an appropriate manner in the DRG system.

As an important consideration, the DRG system has to develop continuously and learn to sustain the rising costs. After introduction of the DRG I98Z in 2007 in the DRG system, an adaptation and differentiation of this DRG is necessary. Besides the complex TNP-therapy, the new DRG should include patients with primary tissue defects needing complex procedures. Tissue defects cause in case of long-term therapy extensive costs for the health insurance companies. Thus, the discussion about refunding of outpatient TNP-therapy has been going on for years. In cases where it is possible from the medical point of view, outpatient therapy would lead to enhanced quality of life for the patients and to a reduction of hospital costs and lengths of hospitalization. However in other countries (USA, Great Britain, Austria and Switzerland) outpatient TNP-therapy is already an established practice [21], the IQWIG (Institute for Quality and Efficiency in Health Care, Germany) refused the absorption of outpatient TNP therapy costs due to insufficient existing research data concerning this topic [22]. The accomplishment of prospective randomized studies would likely change the cost-refunding situation for outpatient TNP-therapy.

The presented work focused on the presentation of the developed method of gaining a cost analysis, as well as on the analysis of the real arising costs of TNP therapy of traumatic wounds. Therefore, we did not analyze the surgical treatment itself. However, evaluating the number of operations in the total collective, there were average 5.9 operations necessary per case (Table 7). This has to be related to the high PCCL-level of 2.99, indicating the severe injuries of our patients. With mostly 1–2 operations for the osteosynthesis and one operation for the final wound closure, there remain average 3–4 operations for changing TNP dressings. Often, not only the wound situation requires a conditioning about several TNP steps, but also the general situation of the patient is critical (high PCCL) and does not allow extended flap surgery in an early step. The department for Trauma Surgery, Plastic

and Reconstructive Surgery, University Hospital of Goettingen, as Level-A Hospital, performs their therapies according to the current actual treatment guidelines of the representative associations (DGOU and DGPRÄC, German Association of Orthopaedic and Trauma Surgery, German Association of Plastic, Reconstructive and Aesthetic Surgery). So it can be assumed, that there are no treatments performed, which would expand the arising costs or distort or the representativeness of the evaluated results.

However, the suppliers have to revise carefully the undergone therapies. Even if the treatments were done according to established standards and guidelines, there might be in some cases an opportunity to close the large tissue defects earlier by plastic-reconstructive methods. This could reduce the length of stay of the patients and therewith the main cost fraction of this treatment collective.

The use of standardized accounting can be a strategically effective method [23]. With the use of a disease-costing analysis a tool of economic evaluation has been applied to analyze costs of a special therapy. Within activity-based costing, modules for establishment of clinical pathways were developed. On this basis, further therapies of other diseases can be analyzed for their cost-revenue ratios. An enhanced degree of cost-transparency can now be reached and realization of further analyses will be simplified.

Notes

Conflicts of interest

None of the authors has a commercial association or financial interest in any of the products, devices, or drugs mentioned in this article that might constitute a conflict of interest.

Authorship

The two authors Leila Kolios and Georg Kolios are to be considered equally as first authors.

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Corresponding author:

Leila Kolios, M.D.
 Department of Trauma Surgery, Plastic and Reconstructive Surgery, Georg-August-University of Goettingen Robert-Koch-Str. 40, D-37075 Goettingen, Germany, Phone: 0049-551-39-22642, Fax: 0049-551-39-8991
 leilakolios@freenet.de

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