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Cost-Effectiveness Analysis of Replantation Versus Revision Amputation Surgery in Single Digit Amputation of the Index Finger: A Decision Analysis Model

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Objective: The success of a finger replantation surgery is determined by many factors. The decision whether or not to replant an amputated part must be taken into consideration given the current economic situation in the country. The objective of this article was to determine the cost-effectiveness of replantation versus revision amputation surgery in a single digit amputation of the index finger at the level of the proximal phalanx.
Methods: Costing for the two modes of treatment up to return to work was taken on the prevailing costs of hospital admission in a charity service in a government tertiary hospital. Probabilities for events and outcomes for the two treatment modalities (replantation versus revision amputation) were determined through literature reviews and meta-analysis. Utilities were taken from disability adjusted lifeyears (DALYs) recommended by the WHO on single digit amputations. A decision tree was constructed and a fold-back analysis was performed to determine optimal treatment. A 1-way sensitivity analysis was used to determine the effect on decision making of varying outcome probabilities and utilities. Finally, the cost-effectiveness ratio was determined to know which treatment modality was the most cost-effective.
Results: The total costs (direct and indirect costs) for replantation and revision amputation surgery were PhP60,000.41 and PhP18,944.25, respectively. Using the decision analysis model and fold-back analysis, the expected value for the revision amputation surgery was higher (0.104) compared to replantation surgery (0.06). Measuring the cost-effectiveness of the two treatments, the replantation surgery cost-effectiveness ratio (CER) was 19,330.10 compared to only 4,700.80 for the revision amputation surgery. Thus, this analysis showed that the revision amputation was the optimal and most cost-effective treatment for single digit amputation of the index finger.
Conclusion: Revision amputation was the optimal strategy based on literature and expected utilities compared to replantation surgery in single digit amputation of the index finger. However, in the clinical setting, the need for the single digit outweighs the results of amputation surgery, thus individualized treatment should be exercised.

Key words: cost-effectiveness study, cost-analysis, revision amputation, digital replantation

Traumatic injuries cause 10 percent of mortality and 15 percent of disability worldwide.[1] There are about 10,000 cases of job-related amputations in the United States each year, 94 percent of these involve fingers.[2] Advances in the realm of trauma and microsurgery have allowed the possibility of finger or hand reattachment and replantation.

The use of an operating microscope allowed blood vessel with diameters of 1mm or less to be repaired to maintain the viability of structures such as an amputated finger. Perhaps the epitome of microsurgery in orthopedic surgery is replantation surgery. Digital replantation became a reality when Komatasu and Tamai[3] successfully replanted an amputated thumb in the 1960s. Since then, finger replantation has evolved throughout the world. Success rates for finger replantations worldwide have reached over 70%.[4-6]

In the Philippines, only certain centers are equipped with an experienced staff and necessary equipment to perform such procedures. Most of these centers are concentrated in Metro Manila. The Microsurgery Unit database of the Department of Orthopedics-Philippine General Hospital showed only 15 patients from 2004 to 2008 had replantation or revascularization procedure for the hand.[7] The success rate in terms of survival of the vascularized or replanted part was 72.2%. Functional success rates in the long term, however, were not yet available. Most of these patients were either temporary or contractual factory workers with no benefits and were admitted in the charity wards of the hospital. Being admitted in a government tertiary hospital would mean no room or doctors' fees. However, the rest of the cost would be shouldered by either the patient or a third-party payer. In an amputated or nearly amputated index finger, two surgical options exist for the patient: either replantation surgery or a revision amputation. An amputated index finger at the proximal phalanx (Figure 1) if not replanted and not revised, may impede thumb-middle finger opposition. A revision amputation is usually a ray amputation (Figure 2), which will create a widened 1st webspace and unimpeded thumb-middle finger opposition.

Figure 1. Patient's hand showing the amputated index finger.

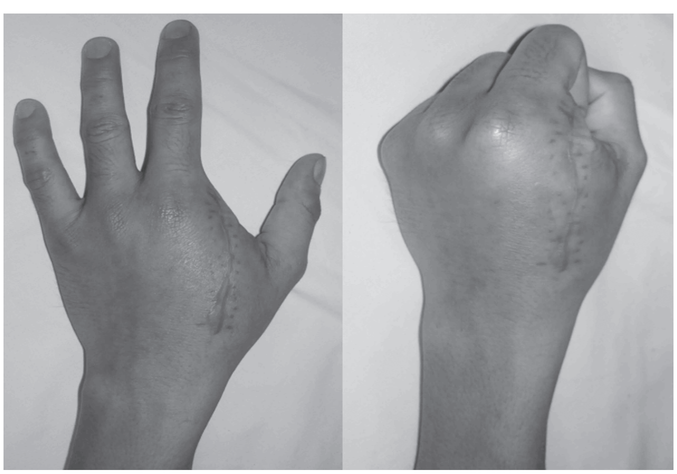

Figure 2. Patient's hand after the revision amputation.

The mechanism of injury, costs of treatment and rehabilitation, expected functional outcome and the possibility of repeated surgery to increase function should be taken into consideration before a choice is made. For a replantation surgery to be chosen, the anticipated function should be better or equal to that achieved with revision amputation. This is because not all amputated index fingers are candidates for replantation surgery. Single digit amputation is a relative contraindication to replantation except in children.[5]

Expected-value decision analysis is a methodological tool that is based in gaming theory and allows for the quantitative analysis of decision making under conditions of uncertainty.[8] The process of creating an "expected-value" decision analysis involves the creation of a decision tree to model a specific problem, the determination of outcome probabilities, fold-back analysis to determine the optimal decision and sensitivity analysis to determine the effect of varying outcome probabilities on decision making. By creating a decision analysis model, simplification of a complex problem-such as in this case of replantation versus revision amputation surgery into a simple model is done. The approach in this research was based on existing literature that replantation of the index finger does not often result in a good outcome.

To gain more insight on which decision a laborer with a single digit amputation of the index finger should take, the investigator used an expected-value decision analysis based on a cost effectiveness analysis method to determine the optimal management strategy for amputations of the index finger. The purpose of this paper was to determine the cost effectiveness between replantation surgery and revision amputation surgery of a single digit amputation of the index finger.

Methods

A cost effectiveness analysis based on an expected-value decision analysis model on replantation versus revision amputation surgery was done.

Data Collection

In creating a decision analysis model using a cost effectiveness analysis method, the following strategies were done: 1) defining a specific question, 2) creating a decision analysis model, 3) assigning values to the outcomes of the model, 4) assigning probabilities to the chance events, 5) identifying the best course of treatment based on the model and 6) sensitivity analysis.

A decision tree (Figure 3) was made to model decisions, their chance outcomes, and the value of those outcomes. There are three components of a decision tree: choice nodes, chance nodes and outcomes.

Choice nodes – represent a situation where a choice is made from a predefined set of actions. This will be based on evidence from literature and current practice.

Chance nodes – represent a set of possible results from an action. This will be based on evidence from literature

Outcomes/Terminal nodes – are possible ends resulting from the chance nodes.

The fundamental determinant of value decision is utility. Utility is a measure of a decision maker's relative preference for an outcome [9]. Perfect utility is 1 and death is 0. All other states fall somewhere between these two values. The actual values can be obtained from expert opinion or published data. For the purpose of this study, time constraints and WHO recommendation using disability weights incurred from disease or injury,[10] the disability adjusted life years (DALYs) was used. If there was no disability weight, an expert opinion from a hand surgeon was sought to assign a disability for the DALY.

The probabilities of the chance events: good outcome versus poor outcome was based on the available evidence from the literature. All the data from the literature were averaged for the good and poor outcome for each surgical strategy.

The decision tree was constructed with one choice node (replant vs revision amputation), 2 chance nodes (outcomes of replantation; failed replantations/revision amputation), and 6 terminal nodes (good or poor outcomes). The failed replantation eventually underwent revision amputation surgery and that the outcome of this was assumed the same as the outright revision amputation surgery.

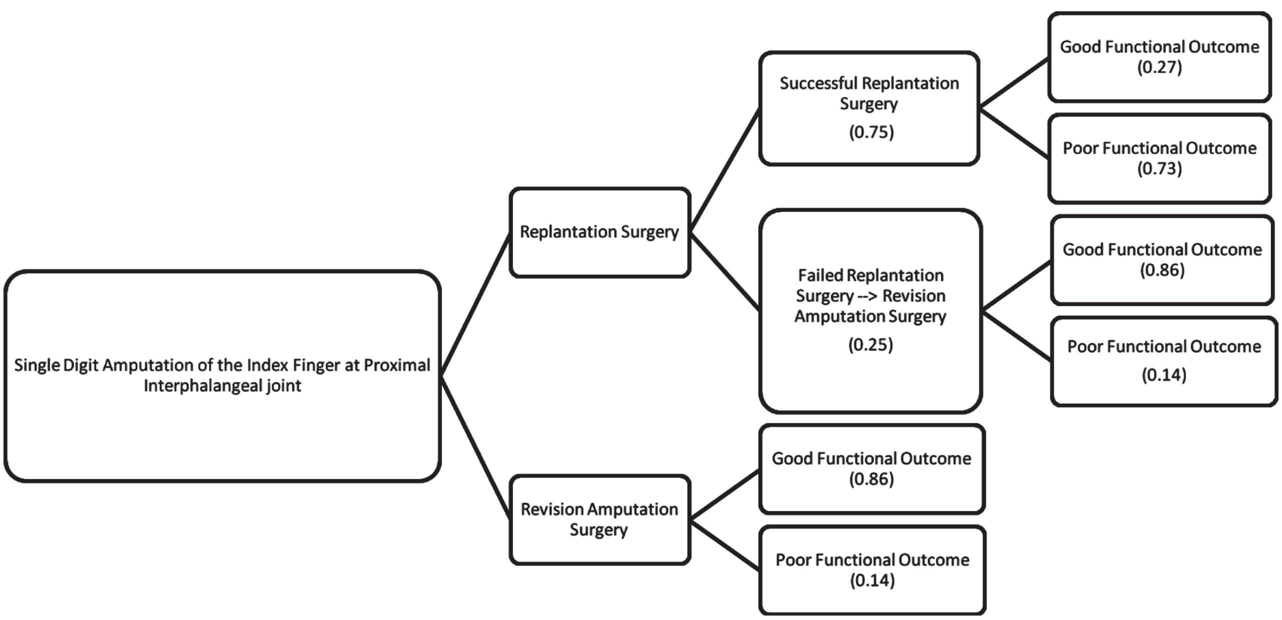

Figure 3. Decision analysis tree.

The fold-back analysis was performed to identify the optimal strategy. Each outcome disability weight multiplied by its associated probability gave an "expected value" for each clinical end point or terminal node (ie good or poor outcome). The expected values for each end point were summed up for a given management strategy and the ultimate expected values of the different strategies were compared. The management strategy associated with the highest expected value was optimal for the given outcome.

An inherent problem with the decision analysis model is that most are estimates and data are never exact. A sensitivity analysis was done to identify and examine the limitations of the data and determine how stable the model is. In this case model, the data success rate for replantation surgery (good outcome) was altered to an acceptable one: from 27% to 95%. This served the author's 1-way sensitivity analysis.

Primary Outcome

Cost of Treatment. Based on a patient's perspective, the costs of treatment for each surgical procedure and materials used were all identified by the researchers through the current cost of materials and hospital services.

Secondary Outcome

Surgical Outcome: This was determined through the case records of the Microsurgery Unit. The length of rehabilitation and the return to work in months were reported.

The following variables were investigated:

Direct Costs of Treatment. Direct costs of treatment refer to costs directly related to the process of treatment. These include the medications and materials used in the treatment such as implants and sutures, dressings and splints, including rehabilitation that contributed to the overall management of the disease. These were expressed in Philippine pesos.

Indirect Costs of Treatment. Indirect costs of treatment include costs not necessarily related to the treatment process, but have substantial contribution to the delivery of healthcare. These indirect costs include the lost time from work. These costs also include x-rays, transportation and caregiver costs.

Case Model

A Case Model was constructed for the decision on the cost effectiveness of replantation surgery versus revision amputation.

Patient Background and Assumptions

BL, 29/M, left-handed, bread-winner of a family of 4, who works in a steel factory in Batangas was taken to the UP-PGH ER department for an amputation of the left index finger during work. He supervises the lifting, arranging and placing of metal pieces into a shelf for cutting using a machine. He is a temporary worker but the company has expressed willingness to initially shoulder surgical expenses, which shall be subsequently deducted from his salary. He has no insurance and SSS. A decision was offered to the patient and his family regarding the plan of treatment: replantation of the amputated index finger or outright revision amputation.

Results

Table 1 shows the costs of treatment for replantation and revision amputation surgery, while results of treatment from replantation or revision amputation are shown in table 2. A decision analysis tree was constructed (Figure 3).

In the decision tree, the disability adjusted life years (DALYs) was used. For each outcome, DALY was computed. This was based on life years[11] with the disability x disability weight. If there was no disability weight, expert opinion from a hand surgeon was sought to assign a disability for the DALY. Formulae for the DALY were:

Table 1. Total costs of treatment.

Items	Type of Costs	Replantation Surgery (PhP)	Revision Amputation Surgery (PhP)
	Direct Costs	28,443.41	9,227.25
	Indirect Costs	31,557.00	9,717.00
TOTAL	Direct + Indirect	60,000.41	18,944.25

Table 2. Results of hand function in replantation versus revision amputation surgery.

Author, Year	Replantation Surgery	
	Good Outcome	Poor Outcome
Scott, et al., 1981[12]	0.20	0.80
Urbaniak, et al., 1985[13]	0.18	0.82
Goel, et al., 1995[14]	0.44	0.56
Average	0.27	0.73
	Revision Amputation Surgery	
Goel, et al., 1985[14]	0.90	0.10
Karle, et al., 2002[15]	0.83	0.17
Average	0.86	0.14

DALY = YLL(years life lost due to premature death) + YDL (years with disability)

DALY = life years with the disability x age weight x disability weight x discounting

Chance events refer to the probabilities of a good or a poor outcome based on replantation surgery of a digit versus revision amputation. This was based on literature reviews.[12-15] A summary of the studies which took into consideration the function of the whole hand, and not just the replanted finger are given in Table 2. In terms of success rates of amputation surgery, in a meta-analysis of single digit replantation of the index finger, the success rate was 75%.[16]

A fold-back analysis was done on the decision tree to determine the "expected value" for each choice and to determine the optimum strategy (Figure 4).

The cost effectiveness ratio was calculated using the formula: Total costs / DALY (Table 3)

A one-way sensitivity analysis was performed to model the effect of decision making of varying the

Table 3. Tabulated results for expected values, life years with disability, Disability Adjusted Life Years (DALYs), total costs and cost-effectiveness ratio.

Treatment	Expected Value	Life Years with Disability	DALYs	Total Costs (Direct & Indirect)	Cost Effectiveness Ratio
Replantation	0.08	38.8	3.104	Php60,000.41	19,330.10
Amputation	0.104	38.8	4.03	Php18,944.25	4,700.80

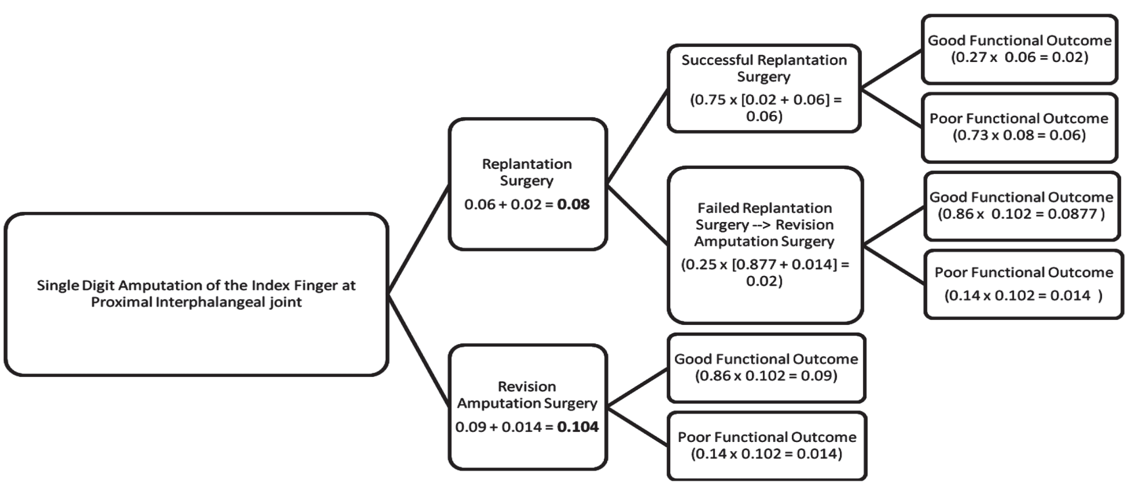

Figure 4. Expected values for the decision tree with fold-back analysis.

results of treatment. In this case scenario, the proportion of good results in the replantation surgery was adjusted from 27% to 95%. The sensitivity analysis showed that even if the probability of a good outcome in replantation surgery was increased to 95% (acceptable/realistic outcome), the cost effectiveness ratio was still higher for the replantation surgery.

Discussion

In this cost analysis report, a scenario where two procedures done on the almost the same type of amputation was present. The cost analysis of treatment showed a great difference in the overall costs for the two procedures: replantation vs revision amputation. From a patient's perspective in a charity service setting, the cost of replantation of a single digit amputation of the index finger was PhP 60,000.41, while that of a revision amputation was PhP 18,944.25.

Indications and contraindications for replantation or revision amputation surgery vary with age, occupation, number of fingers amputated, mechanism of injury, costs to the patient, and expected functional outcome [17]. All these factors should be weighed when a decision is contemplated. Direct costs for replantation surgery is more expensive compared to revision amputation (Table 1). This entailed more medications such as antibiotics, pain relievers, implantation of a metal device to stabilize the bones, and a more comprehensive and longer rehabilitation procedure to improve the functional outcome. In-patient management (while patient is admitted) also meant a longer hospital stay to monitor the viability of the replanted part and more expensive suture materials for vessel and nerve anastomosis. A longer rehabilitation process will be needed to improve outcome of the replanted finger compared to the revision amputation surgery. In a replanted finger, much effort is spent on improving the function of the replanted finger.

Indirect costs for replantation surgery were also greater in the replantation group compared to revision amputation surgery (Table 1). In replantation surgery, a longer time off work was expected compared to an earlier return to work to the revision amputation surgery. A similar study in Sweden by Holmberg, et al.[18] showed that finger replantation surgery was twice as costly as revision amputation and that most of these costs were due to non-surgical factors such as rehabilitation and costs of time off work.

The rising costs of medical treatment, the success of the procedure and their eventual outcome should be taken into account when a decision to replant or to do revision amputation in an amputated part is contemplated. The costs of treatment for each may differ greatly per patient and may cause the patient unnecessary expense for an extended period of time. It is difficult for the surgeon to explain to the patient of which procedure will best suit his injury. Other factors that might come into play for a decision to be made are for example an amputation of a single finger in a pianist versus a laborer. A fine movement for each finger is expected to the pianist compared to a laborer. In this case, replantation may be attempted in the former case. Even if a longer rehabilitation process is expected, the success of a replantation procedure would certainly benefit the concert pianist. On the other hand, a laborer, in whom a viable finger was attached, would have to undergo rehabilitation process which would mean additional expense and longer time off work. However, immediate revision amputation could possibly enable him to go back to work in a few weeks. In this case scenario, individualized treatment is advised and expectations from the surgical procedure of the patient are very important.

In this model, it seems that with the large cost of replantation surgery, the best option of management would be revision amputation. The functional results for each procedure also tend to favor revision amputation. However, based on the authors professional experience, more than 95 percent of patients with single digit amputations of the index finger or any other finger for that matter would want the replantation procedure, even if the costs were evidently higher. In this research, expected values for the replantation were smaller compared to the revision amputation, which makes again the revision amputation the preferred treatment. Cost effectiveness analysis of the research showed that the revision amputation was better with a cost effectiveness ratio of only PhP4,700.80 per DALY compared to PhP19,330.10 per DALY for the replantation surgery.

The limitations of decision analysis models involve the methods by which probabilities and disabilities or utilities were obtained. In reality, the most reliable data may be from meta-analytic studies of randomized trials. However, it is unethical to conduct randomized trials when the decision to replant or not is at stake. In this analysis, paucity of data accounted for discrepancies in probabilities and assignment of disability weights by experts was probably biased. Since our concern is from the patient's perspective, it might be useful to use QALYs (Quality Adjusted Life-Years) instead of DALYs-which is from the experts' point of view. QALYs can be obtained by a variety of methods such as standard gamble, time trade off, or patient trade off.[8,19] However, this was outside the scope of this investigation and may be done in the future.

Model refinement of the decision model may also be done by investigating the internal consistency, external consistency, between-model consistency and predictive validity.[19]

In summary, the cost analysis of treatment from a patient's perspective of replantation surgery compared to revision amputation surgery showed a higher treatment cost for the replantation surgery. A greater percentage of this discrepancy came from the in-patient treatment/ management, rehabilitation and cost of time off work. Although, replantation surgery may seem to be the ideal treatment, individualized treatment planning may be necessary to achieve the most cost effective treatment.

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