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Considering the Use of Maggots in the Debridement of Wounds: A Case Study

Leslie Mayer

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CONSIDERING THE USE OF MAGGOTS IN THE DEBRIDEMENT OF WOUNDS: A CASE STUDY

by

Leslie N. Mayer
Bachelor of Science in Physical Therapy
University of North Dakota, 2000
Bachelor of Science in Biology
University of Wyoming, 1997

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
2001
This Independent Study, submitted by Leslie N. Mayer in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

[Signatures]

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

Title  Considering the Use of Maggots in the Debridement of Wounds: a Case Study
Department  Physical Therapy
Degree  Master of Physical Therapy

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Signature  Leslie Mayer
Date  12/5/00
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ABSTRACT

Maggot debridement therapy is the application of fly larvae to a necrotic wound. Once popular in the 1930s and 1940s, its use declined with the introduction of antibiotics, improvement of aseptic wound care, more aggressive surgical debridement techniques, and its unacceptability by the public. The purpose of this study was to gain a better understanding of maggot therapy, its clinical implications, and to review a medical chart of a Wyoming patient who received this treatment. The material is presented in one concise resource and the protocol included can be evaluated by other clinics using maggot therapy.

A medical chart review was completed of one patient who received maggot therapy two years ago in preparation for a skin graft after a grizzly bear attack. The history, biology, mechanisms of wound healing, indications/contraindications, clinical uses, dressing design, and the advantages and disadvantages of maggot therapy are reviewed. The client included, responded well to maggot therapy and the wound was prepared for the graft in a short period of time.

Maggot therapy is an old form of treatment that needs to be considered by more healthcare workers today for the treatment of non-healing wounds. If it were to be introduced earlier in treatments, rather than after other treatment techniques have failed, faster results may be gained.
CHAPTER I
INTRODUCTION

The use of maggot debridement therapy to heal wounds was common practice in the early 1900s in hospitals nationwide, however their use declined in the 1940s with the emergence of antibiotic drugs, the improvement of aseptic wound care, more aggressive surgical debridement techniques, and the unacceptability of this therapeutic modality by the general public.\textsuperscript{1,2} In recent years, the use of maggot therapy has once again resurfaced as strains of bacteria, such as methicillin-resistant \textit{Staphylococcus aureus} (MRSA), have evolved and become more resistant to certain antibiotics.\textsuperscript{3} A study by Wolff and Hanson,\textsuperscript{4} felt that maggots were responsible for altering MRSA into common \textit{Staphylococcus aureus} and then they healed the stubborn lower leg ulcer.

The patient included within the case study presented with a right lower extremity laceration as the result of a grizzly bear attack in Wyoming. This accident occurred approximately two years ago and the information was obtained from medical records and the hydrotherapy department at a Wyoming facility. The soft tissue injury affected the gastrocnemius, extending down to the fibula, and resulted in an infection.
Problem Statement

Clinicians, as well as the general public, need to be more receptive to alternate treatment techniques in wound care because conservative methods can sometimes fail. Maggot debridement therapy is a natural form of treatment with exceptional healing properties that needs to be further recognized and accepted.

Purpose of Study

The purpose of this study is to gain a better understanding of maggot debridement therapy's history of use, biology, mechanisms of wound healing, indications/contraindications, clinical use, dressing design, and the advantages and disadvantages. In addition, a chart review of a patient who received this form of treatment at a Wyoming physical therapy facility will be included. The case study will assist in better understanding the outcomes obtained with maggot therapy and it will allow other wound care facilities to compare their maggot therapy protocol to the one presented.

Significance of Study

The use of maggots is effective, however maggots are often used as a last resort treatment and are used in few facilities today. Therefore, the material presented in this study allows University of North Dakota physical therapy students, physical therapists, instructors, other healthcare workers, and the general public to gain a better understanding of all aspects of maggot debridement therapy in one consolidated resource. By gaining a better understanding of this technique through reviewing the literature and case study, more healthcare workers may be receptive to their use and learn that positive
results can be obtained through a nontraditional treatment technique. If more conventional measures of wound care are not working with specific patients, maggot therapy should be considered. Maggot debridement therapy may be more effective if it were to be used initially, rather than as a last resort treatment.

**Research Questions**

1) What is the history of maggot debridement therapy?
2) What are the mechanisms through which maggots help to heal wounds?
3) How are maggots sterilized in the laboratory before they are used clinically?
4) How are maggots used clinically and what type of dressing design works the best?
5) What are some indications and contraindications for their use?
6) What are the advantages and the disadvantages of maggot debridement therapy?
7) What results were achieved with maggot debridement therapy on a specific patient at a Wyoming facility?
CHAPTER II
LITERATURE REVIEW

History

Ancient surgical tools, pictographs, and fossilized bodies have proven that wound care was one of the oldest forms of medicine practiced by man. At that time, science coincided with religion and superstitions and therefore some wounds were seen as outward manifestations of evil. Treatments of these wounds involved making the body uninhabitable to demons, e.g. by beating, starving, and torturing the patient. As societies became more civilized, the effects of certain medications on wound healing and specific treatment techniques were introduced and studied.

The infestation of wounds with maggots has been recognized for several centuries as well as the eventual treatment of necrotic wounds with fly larvae. The earliest reference made to maggots can be found in the book of Job 7:5 in the Bible. "My flesh is clothed with worms and clods of dust; my skin is broken, and become loathsome." The majority of maggot infestations, however, were observed on battlefields. Ambrose Paré has been credited as one of the earliest to observe the beneficial effects of maggots on soldier's wounds. Soldiers during European wars and the Civil War were sometimes left to die on battlefields with open wounds, but when found several days after their injuries were inflicted and still alive, medical officers often found maggots residing in their
dying tissues. In 1829 Baron Larrey, Napoleon’s military surgeon, explained, “these insects accelerated cicatrisation by shortening the work of nature and by producing an elimination of the necrotic cells by devouring them without disturbing living tissue.”\textsuperscript{9(p36)} Joseph Jones, a medical officer in the American Civil War quoted, “I have frequently seen neglected wounds...filled with maggots...as far as my experience extends, these worms only destroy dead tissues, and do not injure specially the well parts.”\textsuperscript{10(p1143)} These wounds healed faster than those without infestation and there were less deaths when compared to soldiers being treated with the therapies of that time period.

The first instance of therapeutically using maggots intentionally has been credited to J.F. Zacharias, another Confederate medical officer in the Civil War, in the 1860s.\textsuperscript{1,10} He noted that maggots “in a single day would clean a wound much better than any agents we had at our command”...”I am sure I saved many lives by their use.”\textsuperscript{10(p1143)} However, the presence of infection caused by anaerobic organisms such as \textit{Clostridium perfringens} and \textit{Clostridium tetani} deterred the continuation of their use at that time.\textsuperscript{1} Finally in the 1920s, William S. Baer performed the first clinical study of fly larvae.\textsuperscript{11} Baer was an orthopaedic surgical professor at John Hopkins Medical School in Baltimore, Maryland and prior to his becoming a professor, Baer served as an orthopedic consultant to U.S. forces in France.\textsuperscript{3,4} During World War I he treated two soldiers who had been overlooked on the battlefield for almost a week after fighting had ceased.\textsuperscript{3} The soldiers’ wounds swarmed with maggots, however Baer recorded that the wounds had new or granulated tissue in them and no signs of sepsis or infection
was present. These observations during the war led to his studies and treatments using maggots ten years later.

William S. Baer developed techniques on sterilizing maggots, designing food sources for them, certain treatment techniques, and dressing designs.¹¹ In his study, Baer used 89 patients with chronic osteomyelitis, a chronic inflammation of bone and bone marrow, in a period when the mortality rate of an open fracture in the lower extremity was at 75%. His subjects included both adults and children. The results of his study showed a 90% success rate overall with the total treatment time in children taking approximately six to seven weeks and in adults taking approximately a third longer where other treatments had failed.¹¹,¹² Baer believed it took longer to heal adults because their new bone formation is slower due to a lack of growing cells.¹¹ In adults, there are larger amounts of dense bone present whereas the continual growing bone in children naturally aids in the repair process. It may have also taken longer in adults because their osteomyelitis may have been present longer, therefore causing more bone destruction and larger amounts of scar tissue formation. The results of Baer's study are remarkable because many of his patients had tuberculosis or other intractable infections.¹²

Baer's study led to maggot therapy in the 1930s and 1940s in nearly 300 hospitals nationwide.⁸,¹³,¹⁴ At this time, maggot therapy was used for abscesses, burns, subacute mastoiditis, and osteomyelitis.¹⁵⁻²¹ In the 1940s, however, the use of maggot therapy declined for four major reasons: the introduction of antibiotics, the improvement of aseptic wound care, more aggressive surgical
debridement techniques, and the unacceptability of this therapeutic modality by the general public.\textsuperscript{1,2}

The use of maggots once again resurfaced in the 1990s with the emergence of multiresistant strains of bacteria such as \textit{Staphylococcus aureus}, which have caused antibiotics to be ineffective.\textsuperscript{3} Infected wounds that contain devitalized or necrotic tissue may not respond to antibiotics because the agent in the bloodstream is unable to reach the dead tissue secondary to an ineffective blood supply to that area. Antibiotics also do not facilitate wound debridement and may even retard the process if they inhibit or kill the activity of non-pathogenic proteolytic bacteria, which naturally aid in the reduction of necrotic or dead tissue. In contrast to antibiotics, maggots remove both necrotic tissue and bacteria, leaving a healthy granulating wound.

\textbf{Life Cycle}

Lucilia and Phaenicia both comprise the common greenbottle blowflies.\textsuperscript{8} The adult fly is a metallic coppery-green color hence its common name, the "greenbottle" blowfly.\textsuperscript{3} The word "blow" means to lay eggs and the word "bottle" is believed to be a form of the word "bot", an ancient word for maggot.\textsuperscript{8} It is important to understand the life cycle of this particular species of fly when using them as a form of treatment (Figure 1).
The adult green bottle fly lays large numbers of eggs in clusters or what are known as "rafts". The larvae hatch from the eggs within 12 to 24 hours and are 1 to 2 millimeters in length (Figure 2). The larvae reach maturity within 4 to 5 days, however this number varies depending on temperature, and are now approximately 8 to 10 millimeters in length, approximately the size of a piece of rice (Figure 2). At this time, they stop feeding and look for a place to complete the next stage of their development. The larvae form a puparium, which is produced from hardened skin. Within this new structure, the larva undergoes
metamorphosis and transforms into an adult fly within seven days. Once the adult fly has hatched, it feeds, mates, and then produces its own eggs and the cycle begins again. In addition to understanding this species life cycle, it is also important to understand its mechanisms in wound healing.

**Figure 2.** Approximate Size of maggots before and after Debridement. (Photo by Ronald A. Sherman, University of California). (Reproduced by permission from Sherman RA: Maggot therapy project Available at: http://www.ucihs.uci.edu/path/sherman/home_pg.htm, 1995)

**Mechanisms of Wound Healing**

Several different theories have been suggested regarding how maggots cleanse and heal wounds. These include:

1) Liquefaction of necrotic tissue by the secretion of proteolytic enzymes;
2) Digestion of necrotic tissue and microorganisms as food by larvae;
3) Mechanical washing out of bacteria by the serous exudate caused by the irritating effect of maggots in the wound;
4) Change in the wound pH from acidic to alkalitic as a result of the formation of ammonia.
5) Formation of granulation tissue resulting from mechanical stimulation of viable tissue caused by the continuous crawling of the larvae\textsuperscript{21};
6) Intrinsic factors within the maggot causing growth-stimulating effects\textsuperscript{25};
7) Destruction of bacteria by antibacterial substances (allantoin).\textsuperscript{26-28}

Proteolytic enzymes are endogenously produced proteins that breakdown necrotic debris resulting from cell breakdown.\textsuperscript{29} These enzymes, whose activation is precisely regulated, serve many functions in normal situations as well as those situations which are pathological. Proteolytic enzymes are involved in the regulation of cell maturation and multiplication, collagen synthesis and turnover, the development and removal of the perivascular fibrin cuffs found in venous insufficiency and leg ulceration, and the removal of dead tissues after inflammation. It is believed that maggots produce a powerful mix of proteolytic enzymes, which cause a liquefication of the necrotic tissue inside the wound.\textsuperscript{30} The liquefied substances are ingested as well as possibly absorbed through the maggot's integument to be used as a food source.\textsuperscript{31} A study by Sinclair and Ryan\textsuperscript{29} researched the use of synthetic proteolytic enzymes being used topically as a form of treatment in wound care. Because most topical agents do not seem to penetrate the entire depth of wounds, one consideration of this experimental treatment should be whether or not this cream has the ability to reach desired targets and depths.

A study by Vistnes, Lee, and Ksander\textsuperscript{30} on the proteolytic activity of the blowfly Calliphora erythrocephala larvae, involved the effects of larval secretions on experimental burns. It was shown that the secretions of these larvae digested
the eschar on the burned skin of experimental rats in vivo (on the living organism) and in vitro (in a test tube) when applied as a topical cream. The burns treated with larval secretion cream were further debrided than the burns treated with regular cream, proving that larval secretions could be a potential agent for the removal of burned, necrotic tissues.

Wound pH and the presence of ammonia is another theory as to how maggots heal wounds. When maggots feed on meat, animal debris, and wounds, the odor of ammonia develops. A study by Robinson and Baker, reviewed whether or not the ammonia found in wounds was produced by the maggots themselves or by the bacteria, which naturally reside in their digestive tract. Urea, one of the final products of protein metabolism, is found in blood and lymph, and therefore is present in human as well as all animal tissues. The enzyme urease is also found in several organisms including bacteria, fungi, plants, and animals. Enzymes are proteins that change the rate of a chemical reaction. The ammonia is formed when the enzyme urease comes into contact with urea to break it down. The study by Robinson and Baker proved that urease is present in both the excretions and tissues of Lucilia sericata (sterile and non-sterile larvae), the species of blowfly used in wound care today. The urease that is present in the maggot excretions comes into contact with the urea, which is present in the wound bed of the patient. Ammonia is formed by the joining of these two substances and therefore produces an alkaline environment inside the wound. William S. Baer and others have proven that "wounds with an alkaline reaction healed faster than those inclined to be acid."
noted that most wounds have an acid reaction but once the maggots were introduced into a wound, it took only about 24 hours to become alkaline.\textsuperscript{11} He believed alkaline wound beds caused sterilization of the wound and the killing of any bacteria present.

Another theory as to how maggots heal wounds, involves the possible secretion of growth factors by maggots. A study by the Department of Veterans Affairs Medical Center in Long Beach, California\textsuperscript{25} researched the growth effects of \textit{Phaenicia sericata} larval extracts on fibroblasts. This study exposed human fibroblast tissue culture to hemolymph (blood and lymph) as well as alimentary extracts from the maggots. The growth effects of maggot extracts were compared to those of epidermal growth factor, recombinant interleukin 6, and the insect hormone 20-hydroxyecdysone. This study found that maggot extracts stimulated significant increases in human fibroblast numbers, therefore suggesting that maggots have intrinsic factors that might be responsible for the growth stimulating effects seen in wounds infested with maggots. The release of these growth factors by the maggots may be responsible for the stimulation of new granulation tissue.\textsuperscript{33} However, the stimulation of newly granulated tissue may also be due to the constant movement of the maggots within the wound.\textsuperscript{1}

One final theory as to how maggots debride wounds and promote wound healing includes the destruction of bacteria in the wound through excretions, which contain antibacterial substances. A study from 1934 by William Robinson\textsuperscript{26} determined that urinary excretions from both sterile and non-sterile maggots contain allantoin. Allantoin is the principle terminal product of purine
metabolism and results from the oxidation of uric acid. It not only is found in maggot urinary secretions but also is common in plants and animals. The allantoin for the study was obtained commercially and was applied to ulcers, burns, and wounds with little granulation. Local granulation was found where the allantoin was applied after just a few treatments.

It has been researched that several other species of insects possess the ability to produce antibiotic-like agents. Studies on the screw-worm, a species not used in maggot therapy, suggest that antimicrobial agents including phenylacetic acid and phenylacetaldehyde are formed by the bacterium *Proteus mirabilis*. *Proteus mirabilis* naturally resides in the gut of the screwworm and it is believed that the bacteria remaining in the wound bed, which are not ingested, are killed by chemicals produced by this bacterium. This bacteria may be the one responsible for the killing of the bacteria in the wound bed.

There are still many unanswered questions as to the exact mechanism that maggots use to cleanse and heal wounds. It may only involve one of the theories listed above or it may be a combination of several.

**Maggot Sterilization**

The purpose of using maggots in wound care is to clean out any existing infection and/or necrotic tissue therefore, it is important that the maggots be sterile so they do not introduce additional bacteria. Sterile medicinal maggots indicate that the maggots to be used in therapy are "disinfected" or free from bacteria. Although sterile, maggots are still capable of maturing into adulthood,
however it should be remembered that maggots are sexually immature and are incapable of reproduction until they have pupated into adult flies.

William S. Baer was the first to clinically study maggots and he was the first to develop a process in sterilizing them in the laboratory. Initially Baer attempted to sterilize the maggot itself rather than the egg. Through several trials, he found that the intestinal tract did not become sterilized with this method and that is where some bacteria reside in the maggot. This method did not work because only the external surface of the maggot became sterilized and not the inside. Baer decided that the egg must be sterilized in order for the process to work. The test tubes used to house the eggs were sterilized in hot air at 160 °C for one hour. The eggs were then divided and placed into different test tubes. Next, the sterilizing solution of ethyl alcohol, hydrochloric acid, and mercury bichloride was poured over the eggs in the test tubes. The eggs were immersed in this solution for a total of thirty minutes. In order to wash the eggs, they were first strained with gauze and then sterile distilled water was poured over them. Finally, the eggs were transferred to bottles that contained sterile food. The sterilized food consisted of agar culture media liquefied, Fleischmann's yeast, and pig liver. The liver was chopped up into cubes, covered with water, and was allowed to boil for twenty minutes. The yeast was added to the liquefied agar and then was poured over a cube of liver inside a bottle. The bottles, each containing a cube of liver, were then sterilized for thirty-five minutes at fifteen pounds' pressure. Next, the bottles were incubated at 37° C for thirty-six hours and then were sterilized again for the same amount of time and pressure.
Today, different companies have different methods of sterilizing maggots, but all include methods similar to Baer's method of sterilization. One method included in an article by Teich, involved washing the eggs three times with water after removing them from their food source. The eggs were then sterilized with three washes of a solution of sodium hypochlorite (Clorox) diluted 1:50, and then they were hatched in a sterile flask.

A study by Sherman and Wyle stated that they disinfected their eggs by washing them for five to six minutes with 3% Lysol and then three rinses with sterile saline. The eggs were then separated from one another by soaking them in sodium sulfite or sodium hypochlorite. They believed it was crucial to individually separate the eggs from one another before disinfection because otherwise bacteria can become trapped within the egg masses and the disinfectant will not penetrate this area. Baer also believed the separation of eggs was necessary before pouring the sterilizing solution over them and he separated the eggs by stirring the eggs in water. Next, they placed the hatched maggots in a sterile container that contained the food source of sterile raw chicken.

A study completed by Mumcuoglu et al. "surface sterilized" their maggots with 1% sodium sulfite in physiological saline that contained 2.5% formaldehyde. Next, the eggs were transferred to a container that consisted of a mixture of pureed liver, and agar containing kanamycin monosulfate. After hatching, the larvae were washed with sterile distilled water. After washing, they were surface
sterilized again with 3.5% formaldehyde in physiological saline, washed with distilled water, filtered through a sieve, and stored in sterile Eppendorf tubes. In order to make sure their sterilizing process was successful, some facilities that raise maggots have their maggots cultured in a laboratory before they are sent off for use in clinics. The facilities that raise the maggots may have their own laboratory equipment available for culturing or they may send the maggots to be sampled at a local hospital.

Indications and Contraindications to Maggot Therapy

Today, a majority of patients treated with maggot therapy have ulcers, pressure sores, or traumatic wounds which have become infected. These ulcers include diabetic foot ulcers (arterial ulcers), venous stasis ulcers, and other neurovascular ulcers. Ulcers can develop, for example, in patients with diabetes who have poor circulation. Pressure sores develop in patients who have been bed-ridden for extreme periods of time and therefore their blood pools. Poor circulation or pooling blood can lead to tissue cell death and therefore necrotic tissue develops. Maggot therapy is also used for patients who require pre-surgical debridement and for those patients with post-surgical wounds that are not healing with other forms of wound treatment. It can also be used for osteomyelitis, as Baer researched years ago, as well as for any gangrenous tissue. Gangrene is the death of tissue cells secondary to the blockage of blood supply to a wound and if it is not removed, the tissue will rot. Maggot therapy is also indicated for wounds that have antibiotic resistant strains of bacteria like methicillin-resistant *Staphylococcus aureus*. Other uses have
included cellulitis, mastoiditis, abscesses, cancerous tumors, and recently maggot secretions have been used to treat burns.\textsuperscript{9,21,23,30} In cases where maggot therapy was used to treat cancerous tumors, it should be noted that maggots cannot be used as a cure for cancer but studies do indicate they may decrease tumor size or can be used for palliative care.\textsuperscript{3}

Maggot therapy is not appropriate for all patients and certain contraindications should be considered before its use. Maggot therapy should not be used on wounds that bleed easily and they should not be placed in wounds that are located near large blood vessels or those associated with a body cavity or organ.\textsuperscript{39} One final contraindication involves the psychological status of the patient. If the patient is unable to handle the idea of maggots as a form of therapy, then they are not a candidate for this form of treatment.

**Clinical Use**

The species of fly larvae used clinically today is \textit{Phaenicia Sericata} (green blowfly) or \textit{Lucilia sericata}.\textsuperscript{3,39} Any licensed physician can prescribe maggot therapy in the clinic, but most commonly, plastic surgeons or orthopedic surgeons will order their use. Some physicians apply the maggots themselves, but physical therapists, nurses, nursing assistants, and even entomologists can apply them.\textsuperscript{22} The patient will have consented to their use prior to beginning treatment and they will be informed on their use and what is expected with this form of therapy.

Prior to applying maggots in the clinic, the size, shape, amount of exudate, and the odor of the wound should be recorded. It is important to measure the
wound’s length, width, and depth as well as the amount of necrotic tissue and newly granulated tissue present. Sometimes wounds are traced onto a sterile plastic sheet with a grid to keep in the patient’s chart. The number of maggots that should be introduced into the wound is dependent on the wound’s size. A general rule is that no more than ten maggots per centimeter squared should be applied to a small wound and even less if there is a smaller amount of necrotic tissue present.

The maggots arrive in a sterile container with a lid. The lid contains a filter that allows air to enter but not microorganisms. They are usually ordered in units and one unit contains approximately 1000 maggots at a price of approximately $80. Within the sterile container, there is a 4 x 4 soaked with nutrients to provide a moist and somewhat humid environment. Occasionally upon arrival some of the maggots may have dried up and died and will look like a black speck. Most companies who supply facilities with maggots will ship them overnight for next day delivery. It is generally a good idea to use the maggots within one day after their delivery, but if they are not used immediately they can be kept up to five to seven days if properly stored in a refrigerator at or slightly above 5 to 6 °C. While refrigerated, a moist gauze pad should be placed in the container every so often to keep them moist so they will not dry out. The maggots should also be removed from the refrigerator twice a day for one hour to prevent them from freezing. The application technique and the dressing design vary among facilities and the company who provides them.
To apply maggots to the wound, the maggots can be swiped from the vial onto a saline-soaked 4 x 4 pad and then loosely pack the 4x4s into the wound bed. The gauze application of the maggots allows for easy handling of the maggots and gives the maggots a "larger area through which to crawl before reaching the wound margins and escaping." Another method to remove the maggots from the vial is to pour a small amount of saline into the vial with the maggots. Swirl the saline around in the vial to loosen the maggots from the sides of the vial. Then, strain the vial contents over a piece of chiffon, remove the maggots from the chiffon with a tongue depressor and then place inside the wound. Once the maggots are placed inside the wound bed, the maggots have a tendency to congregate together and they use their mandibles to latch on to the necrotic tissue on which they will feed. Next, the dressing is applied to the wound and includes a "cage-like" design. The dressing should not only contain the maggots, but also allow oxygen to enter and the liquefied necrotic tissue produced by the maggots to seep out. The maggots are left in place anywhere from 24 to 72 hours. If the larvae are left in the wound longer than this amount of time or after they are satiated, the next stage of development (pupation) will occur. If the maggots try to pupate within the wound they will do so in either the tissue itself or in the gauze that is inside of the wound. If the dressing becomes loose during the treatment time, then the edges of the dressing should be taped down with a hypoallergenic tape to prevent further escaping. If the entire dressing comes off, then the patient should come in to the clinic and the process of application should be repeated.
After 24 to 72 hours, it is time to remove the maggots from the wound. A red biohazard bag should be placed next to the wound, or if it is an extremity, within the bag itself. The dressing is removed and the wound is rinsed with a bottle of saline. By rinsing the wound into the bag, the maggots and dressings are quickly and properly contained and environmental services can be contacted to properly dispose. It is not recommended to use a whirlpool or Hubbard tank for the removal of the maggots because the maggots can get into the whirlpool's agitator. This would make it hard to clean and the chemicals used in cleaning the whirlpools may not kill the maggots thoroughly. Once the dressing is removed, the 8 to 11 mm maggots now full of food, may be seen feeding in the "head down" position and tunneling tracts may be noted. The amount of necrotic tissue will determine the number of sessions needed with maggots, as ordered by the patient’s physician. Nearly half an ounce of dead tissue can be digested each day by the average dose of maggots. The process of therapy may need to be repeated once or twice a week or until the wound is healed. Sometimes one session is sufficient, whereas wounds with large amounts of necrotic tissue may need several weeks of therapy. Indicators that maggot therapy should be discontinued are a decrease in wound odor, decreased wound drainage, and healthy red granulating tissue in place of the necrotic tissue. A majority of clinics discharge maggots when the wounds are free of necrotic tissue, however William S. Baer continued their use until the wound was completely filled with granulation tissue. By extending the maggot’s use, re-infection with bacteria may be prevented as well as the build-up of sloughy debris. One clinic noted that
the maggots have a tendency to leave behind a “silvery-slimy tissue” that they do not want to ingest. Because of this, it is necessary to use another form of debridement in addition to the maggots. In Baer’s study,\textsuperscript{11} it was felt that a “scum” left over the newly granulated tissue may be due to \textit{Proteus bacillus}, a persistent bacteria that remained in the wound.

\textbf{Dressing Design}

The maggot therapy dressings used 60 years ago were rather elaborate, time consuming, and expensive.\textsuperscript{42} Today, the types of dressings used in maggot therapy will vary among facilities and the materials available. Most facilities find that dressing design is a process of trial and error and is a technique learned from mistakes. Selection of the dressing is an important part of this type of treatment and several things should be kept in mind when designing the dressing.

The dressing should be “cage-like” in order to keep the maggots from escaping the wound bed throughout the course of treatment. It is important to keep the maggots within the wound because they may leave the wound once they are full or when it is time to bury themselves for pupation, the next stage in their development.\textsuperscript{42} The dressing should allow oxygen to enter the wound bed but at the same time should absorb liquefied necrotic tissue that the maggots have produced. The dressings should be easy to apply, simple to maintain, durable, and inexpensive. Sometimes the powerful proteolytic enzymes that the maggots secrete can be irritating to healthy tissue causing the surrounding tissue to become red and this should be considered when constructing a dressing.
design in maggot therapy. This redness may be due to the maggot secretions or it may be a bacteria present on the wound borders that is not visible to the therapist but is recognized by the maggots.

One type of dressing design suggests surrounding the wound with DuoDerm, a type of hydrocolloid dressing, and then applying a layer of Mastisol over the DuoDerm. DuoDerm provides a moist healing environment, however maceration may occur with large amounts of wound exudate. After the maggots are placed inside the wound, a piece of chiffon, larger than the wound, is put in place over the DuoDerm. The chiffon is secured with another layer of Mastisol followed by DuoDerm. Next, a 4 x 4 is placed over the previous, or if the wound is on an extremity, a Kerlix roll can be used to hold everything in place.

Another dressing design that may be quicker than the previous, fits a piece of Derma-net over the wound bed once the maggots are in place. The Derma-net is edged with Hypa-fix tape, a cloth-like tape, to prevent maggots from escaping the edges of the dressing. Next, an ABD pad is put into place and then burn net is used to hold the entire dressing in place.

Other designs have been made using hydrocolloid dressings and zinc paste bandages to better contain the maggots. Sometimes, hydrocolloid dressings cannot be used because of a wound's location or if the patient has overly sensitive skin. In this case, a zinc paste bandage can be used in place of the hydrocolloid. A dressing design that uses hydrocolloid, described cutting a piece of hydrocolloid to fit the wound size. Next, a sterile piece of fine nylon
mesh was cut larger than the wound size but smaller than the already cut hydrocolloid dressing. The nylon mesh was taped to the back of the hydrocolloid dressing. To cover the hydrocolloid, an absorbent pad was put in place to absorb any exudate from the wound. This outer absorbent pad is beneficial because it can be changed without disturbing the primary dressing.

A study by Ronald Sherman\textsuperscript{42} described his "most successful" dressing design (Figure 3). This technique first applied DuoDerm directly to the skin surrounding the wound with a hole cut in the center of the dressing to surround the wound. Next, two coats of Skin Bond Cement were spread over the DuoDerm. The maggots were then introduced to the wound through the opening that was cut into the center of the DuoDerm. A sterilized piece of chiffon was placed over the DuoDerm and wound bed and was glued in place with the cement. Next, silk tape was placed along the chiffon to further adhere the chiffon to the DuoDerm. Finally, a transparent ring of semipermeable membrane sheet was placed over the silk tape and over part of the surrounding skin. A semi-permeable membrane film is a transparent tape-like substance. It is permeable to moisture vapor and oxygen but not to bacteria and water.\textsuperscript{44} This final layer was put into place to help protect the dressings from soiling and to "act as an effective second-line barrier to the occasional maggot that managed to navigate between the skin and the DuoDerm."\textsuperscript{42(p453)} A final gauze pad was placed over this entire design to absorb any drainage produced from the wound and could be changed every so often as needed. If the top gauze pad were left in place too long, it would become too moist from excessive exudate and would
cause the dressings below to loosen. This study proved this dressing design to be very successful and reduced the frequency of maggots escaping to less than one percent of all maggot dressings applied. The average length of time to apply this type of dressing was approximately 30 to 45 minutes. Although this dressing design is time consuming, the prolonged survival rate of this dressing and the reduced frequency of maggots escaping “have more than compensated for the extra effort required to construct it.”42(p454) This dressing design is also worth the time in its construction because it allows the wound bed to be directly observed throughout the patient’s treatment. One disadvantage of this dressing design would be that if a large number of maggots were introduced to the wound and the dressing was applied too tight, pressure damage could result. If the wound is located in an area where a hydrocolloid ring or a sheet of chiffon are unable to be used, then a nylon stocking can be applied. The stocking has the advantage over the chiffon of stretching, therefore allowing the wound to expand. Sherman also found that by coating the surrounding skin of the wound bed with a skin protectant like Shield Skin, the tissue was less likely to become inflamed and the adherence of the DuoDerm was also improved.
Figure 3. Optimal maggot debridement therapy dressing design (Reproduced with permission by Sherman RA: A new dressing design for use with maggot therapy. Plast Reconstr Surg. 100:451-456, 1997)

A study by Thomas and Andrews,45 examined the effects of hydrogel dressings on maggot development. Hydrogels are "three-dimensional, water-swollen, cross-linked structures" which have the "ability to absorb or donate fluid, depending on the nature of their formulation and the state of hydration of the wound."45(p75) They are thought to "promote autolytic debridement by increasing the moisture content of slough and necrotic tissue, thus facilitating enzymatic activity."45(p75) This study was made because many times maggot therapy is used as a last resort treatment method and therefore traces of other products in the wound are left from prior treatment methods. It was believed that certain
brands of hydrogel were having effects on the development and survival of the larvae in the wound. The study examined the effects of six different brands of hydrogel: Aquaform, Granugel, Intrasite, Nugel, Purilon, and Sterigel. Fresh pig liver was blended with different percentage amounts of the six different brands of hydrogel. Next, the larvae were introduced to each sample and left to feed on the liver for 48 hours. At the end of the 48 hours, the larvae were counted and weighed. All the gels but one contained propylene glycol, therefore it was necessary to carry out a second study to determine the effect of this substance on larval survival and development. Propylene glycol is added to gels in order to prevent the gels from drying out and also to prevent the growth of microorganisms.

The study found that there was reduced larval growth and there also was an increase in the mortality of the larvae with increased concentrations of Granugel, Intrasite, Nugel, and Sterigel. With Aquaform, this trend was reversed, however there still was a decrease in larvae development when compared to control values. Purilon gel was found to increase the development of larvae when compared to control values and this is believed to be true because of the absence of propylene glycol. When propylene glycol was added to the liver/Purilon gel mixture in the second part of the study, there was a marked decrease in the development of the maggots. When propylene glycol was added to the liver alone, an even further decrease in larval development was noted. This study also found that when water was added to both the liver/gel mixtures and to the liver alone, the larvae survival and growth rates decreased. It should
be remembered that maggots feed by secreting enzymes which dissolves any dead tissue, turning it into a "liquid soup", which makes for easy ingestion. "In the presence of excess liquid, it is postulated that, if the maggots do not drown, their digestive enzymes become diluted and therefore rendered less effective."\textsuperscript{45(p77)} "The increase in larval development observed with increased quantities of Purilon gel may be attributed to the ability of the gel to absorb excess fluid from the blended liver, resulting in the formation of an increasingly cohesive mass."\textsuperscript{45(p77)} Like the Purilon gel, Aquaform also reduced the fluidity of the macerated liver and this decrease in water content may be responsible for the increased survival rate of the maggots. This study would be important for health care workers using maggots to keep in mind if they feel they are not getting the results usually presented.

\textbf{Patient Education}

Patient education is crucial in any type of healthcare, especially in physical therapy. When first explaining to a patient that maggots are going to be used for treatment, most patients have mixed feelings. It is critical that the patient understands the entire process of maggot therapy prior to initiating their treatment.\textsuperscript{3} It is also important to show the patient the actual size of the maggot to be introduced to their wound. Most facilities have a brochure or video on maggot therapy that is reviewed with the patient prior to beginning treatment.

Begin by explaining the type of maggot to be used in treatment and the mechanism of their wound healing process. All species of maggots are not identical in their actions. Some burrow into healthy tissue, while other species
digest only necrotic tissue. Explain that the maggots are sexually immature, are disinfected, and that they will be removed before it is time for the next stage in their development (pupation). Also explain that the maggots will not enter their bloodstream while inside of the wound bed. Let the patient know that they may feel the maggots moving around inside the wound, a tickling sensation, but that it is normal. This tickling sensation can be a downside to maggot therapy, however a majority of patients treated with maggots have diabetes and therefore have poor sensation in their extremities. The odor during this form of therapy can be quite offensive the first few days because the maggots have stirred up the bacteria in the wound. Odor should decrease as the treatments progress because the maggots feed on the bacteria causing the tissue death. Sometimes a wintergreen spray is given to patients to spray on their outer bandage to help mask the strong odor. Patients will also be concerned with whether or not treatment will be painful. Explain that a majority of patients feel that their wound pain is reduced or completely eliminated during maggot therapy. Cost is another big concern of patients and they should understand that maggot therapy is generally cost effective.

Most healthcare workers, who have used maggot therapy as a form of treatment, have found patients to be remarkably tolerant of their use. As a healthcare worker who is providing this type of treatment, it is important to act confident with what you are doing. If the patient senses you are uncomfortable, they will be uneasy with treatment as well.
Advantages and Disadvantages of Maggot Therapy

The advantages of maggot therapy outweigh the disadvantages and with an increase in resistance of certain types of bacteria to antibiotics, clinicians nationwide need to consider alternative methods of wound management.

Although sterilized maggot treatments can be costly, this treatment is cost effective in the end. For example, a 72-year old man diagnosed with bilateral chronic foot ulcers located on his metatarsal heads was treated for twelve months with conventional measures. These conventional methods included: silver sulfadiazine cream 1%, saline dressings, unna boot therapy, topical enzymes, topical antibiotics, intravenous antibiotics, sodium hypochlorite 0.5%, hydrocolloids, hydrogels, foams, and calcium alginate dressings. After twelve months, no signs of healing were noted. This patient was then entered into a maggot therapy study in 1993 where the left foot was to receive maggot therapy twice a week and the right foot was to continue with the conventional methods of treatment. By the fourteenth week of the study, the left ulcer was almost completely healed where the right ulcer remained unchanged. This specific study reveals how maggot therapy is cost effective because of decreased treatment time in the clinic. Maggot therapy is also cost effective because it can be done as an outpatient; therefore the patient does not have to pay for overnight stays or nursing fees and may even prevent a costly amputation.

Another advantage of maggot therapy is that it takes less time than surgical debridement and the healthy tissue is not damaged. Surgical debridement is a type of semi-selective debridement meaning that both necrotic
and living tissues are removed together, ideally more necrotic tissue being removed than viable tissue. Maggot therapy is a type of selective debridement, meaning only necrotic tissue is removed. Therefore selective debridement is much more advantageous than semi-selective debridement.

Other advantages of maggot therapy are that no anesthetic is necessary and it is less painful than other methods of debridement. Maggots also do not require an excellent peripheral blood supply, which is beneficial for patients with diabetes. The maggots also may actually initiate new tissue growth by secreting growth promoting agents. Maggots are also universally available.

One of the main disadvantages of maggot therapy is aesthetic in nature. It is hard to convince some clinics and patients to use maggots because they are often associated with dirt, decay, and/or death. On a recent episode of an emergency room television series, a patient with gangrene was being treated with maggots 30 mm in length, causing the patient to become hysterical. It is no wonder that patients, as well as clinicians, are skeptical about their use when the actual average size of maggots used in therapy is 2-3 mm in length. Another disadvantage may include a localized pruritis, or itching, however most patients are unaware of the maggots presence. A skin irritation may also develop secondary to the strong proteolytic enzymes released by the maggots. A summary of the advantages and the disadvantages are listed in Table 1.

As of today, maggots are generally used as a last resort treatment method for stubborn wounds that will not heal. After weighing the advantages to the disadvantages, it is clear that maggots should become a regular form of
treatment in wound care facilities worldwide. If maggot therapy were to be used earlier in treatment in place of conventional methods of wound care, it could become even more effective in results and in controlling costs.\textsuperscript{47}

**Table 1.** Summary of the advantages versus the disadvantages of maggot debridement therapy

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cost effective</td>
<td>• Aesthetic in nature</td>
</tr>
<tr>
<td>• Selective debridement</td>
<td>• Localized pruritis (itching)</td>
</tr>
<tr>
<td>• Can Rx as outpatients</td>
<td>• Patients may feel their crawling/tickling</td>
</tr>
<tr>
<td>• No anesthesia necessary</td>
<td>• Leave behind a silvery, slimy tissue</td>
</tr>
<tr>
<td>• Less painful</td>
<td></td>
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<tr>
<td>• Universally available</td>
<td></td>
</tr>
<tr>
<td>• Good peripheral blood supply not necessary</td>
<td></td>
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<tr>
<td>• May initiate new tissue growth</td>
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</tbody>
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CHAPTER III
METHODOLOGY

Instrumentation

Two databases were used to locate journal articles pertinent to this study. Medline is a database that includes articles from international biomedical journals of all languages and includes publications from 1966 to the present. A majority of the references used for this study were located using this database at the Harley E. French Library of the Health Sciences, University of North Dakota. Infotrac's Health Reference Center was another database used at Coe Library, located at the University of Wyoming. For journal articles that were not available at the University of North Dakota, interlibrary loan was used. The Internet was also useful in locating articles and pictures of maggot debridement therapy.

In addition to the databases and Internet, a company that supplies the Wyoming facility included within the case study with their maggots was contacted with a phone call. This company, biomaggot.com, Inc., provided a pamphlet of information regarding maggot therapy and how to use their product clinically. Interviews with a physical therapy assistant who works in the hydrotherapy department were also made on several occasions to answer questions as they arose throughout the research process. Observation of the application of maggot therapy to a patient was made possible at the hydrotherapy department. This
treatment was applied to a patient other than the one included within the study, however through this observation, the application technique was further understood.

**Procedure**

A physical therapist at the Wyoming facility's hydrotherapy department was contacted with a letter describing the proposed project by the researcher. A phone call was also made to the medical records office at this same facility. Once the University of North Dakota's Institutional Review Board (IRB) approved the proposed project, a copy of it was given to the medical records office. This proposed study was presented to the hospital's lawyer and permission was granted. Both departments were willing to participate once permission was approved. Because the copying of any clinical photographs taken in hydrotherapy was not included within the original proposal, a memo was sent to the University of North Dakota to inform them of the change. The University permitted the changes and a copy of the signed memo supporting the change was given to the medical records office. While all of the paperwork was being processed, articles were gathered from the two databases.

Once all of the paperwork was cleared, copies were made from the subject's chart in medical records at the Wyoming facility. Copies of the subject's initial hospital notes (where the subject was first admitted immediately following the accident), EMS reports, radiology reports, surgical reports, physician's orders/evaluations/discharge notes, and physical therapy/hydrotherapy reports/notes were made. These copies were reviewed to gain an understanding
of the subject's accident and the medical procedures performed after the accident occurred. The subject was contacted and informed of the study and the subject provided informed consent for the release of medical records and any photographs taken in hydrotherapy. The subject was contacted with questions that could not be answered after the chart was reviewed. Copies of the photographs taken in hydrotherapy were made after patient consent and were helpful in viewing the progress made in hydrotherapy.

Subject Selection

One subject, who underwent maggot debridement therapy at a Wyoming facility two years ago, was selected for this study. The subject provided written consent to allow the review of his chart at the Wyoming facility's medical records office (Appendix). The subject also provided written consent to allow copies to be made of photographs taken in the hydrotherapy department at this Wyoming facility.

At the time of the intervention, the subject was in good physical condition, had a non-significant past medical history, and had no coexisting medical conditions that would interfere with his hydrotherapy treatments. This subject was recommended by the hydrotherapy department because of the positive results achieved through maggot debridement therapy, his good physical and mental condition, his local residency, and because no other coexisting medical conditions interfered with his treatments. A majority of patients treated in hydrotherapy are elderly and have coexisting medical conditions that sometimes
interfere with their treatments and on occasion death precedes the completion of their treatments. Because the subject lives locally, any needed information could easily be obtained if questions came about.

The hydrotherapy department initially contacted the subject by phone to see if he would be willing to release his medical information for the inclusion within the study. The department gave the subject the researcher's phone number and contact was made that day. A meeting with the subject was necessary so the study could be described in detail prior to informed consent and the consent form could be signed.

Client History

The patient was a 40 year-old white male who works fulltime, enjoys outdoor activities, and is married. He has a past medical history of seizures and a left medial collateral ligament (MCL) repair with screws in 1976 and his medications at this time were not significant.

The patient was camping alone in a Wyoming park when he encountered a grizzly bear. The bear bit him on the right lower extremity, scratched him on the abdomen, and threw him into the air before being driven off with pepper spray. The patient had to hike out of the park alone and then he drove by himself for several miles to a nearby hospital. Upon examination in the emergency room, it was evident that the patient had sustained a huge laceration to the right lower extremity. The wound extended from the proximal tibia in a semi-circular fashion to the distal one-third of the lateral tibia, resembling an "s" shape. The wound extended through the gatrocnemius muscle down through to the fibula. Neither
foot drop nor decreased sensation was present. The peroneal nerve and the vasculature to the leg were all intact and normal. X-rays of the right lower extremity revealed no fractures or osseous deformities, however significant amounts of gas were present as well as soft tissue swelling secondary to the laceration. The bear claw scratches to the abdomen were superficial and did not present a problem. While in the hospital, the patient received surgery the day of the accident. The wound was debrided and a pulse lavage was used to irrigate the wound bed. The loose flaps of skin were approximated with sutures and a drain was put into place. Several 4x4s soaked with Betadine, an anti-infective, were applied to the wound along with a leg splint. The following day, further debridement was performed in the operating room along with pulse lavage and the wound was once again partially closed with sutures. Betadine 4x4s were applied along with Kerlix gauze rolls and an Ace wrap. In addition to the two surgeries, a tetanus vaccination was administered at this facility.

Two days after the accident, it was felt that the patient was strong enough to travel via private vehicle to a larger hospital located in the patient’s hometown. En route to the larger hospital the wound began to hemorrhage and an ambulance was called to intercept the vehicle and complete the trip. In the ambulance the patient was put on oxygen, a pressure dressing was applied, and the lower extremity was elevated. Upon arrival at the second facility, the patient was given one unit of blood and pain medications. The examination at the second hospital revealed that the wound flap, which had been sutured at the initial hospital, was slightly bluish in color and the wound bed had a slow capillary
refill. No purulent discharge or odor was present at this time. Because the skin flap was necrosing, it was anticipated that a split-thickness skin graft (STSG) would be necessary in the future. The physician predicted that there would be complications with infection because grizzly bears are omnivores and predators, therefore their mouths and claws are exposed to microorganisms found in the prey they eat and the dirt they forage.

The patient was kept on bed rest the first few days in the hospital in the Trendelenburg position, where the head is slightly lower than the lower extremities. The wound was left open and the circumference of the wound was measured on a daily basis. The sutures applied at the first facility were removed at this time and some initial improvement in the color of the flap was noted.

**Evaluation/Examination**

Five days after the accident, on September 3, 1998, an evaluation for hydrotherapy was completed and the patient was ordered to receive hydrotherapy on a daily basis. Upon initial evaluation, no odor was present, and drainage was minimal and sanguineous. The color showed black and white slough throughout the wound bed with areas of blue between the three open lacerations. Therapists were unable to accurately assess the amount of necrotic and granulated tissue at this time. There were three different open lacerations and their measurements were taken. The medial proximal open laceration measured a length of 2 cm (centimeters) and a width of 4.2 cm. The medial distal open laceration measured a length of 11 cm and a width of 1.8 cm. The most lateral open laceration measured a length of 27 cm and a width of 4 cm.
Range of motion (ROM) in the right ankle and knee were limited and the ankle was held in plantar flexion when the patient was resting. There was no sensation present in any of the open laceration areas. The patient’s mobility was decreased and the patient did not bear weight on the right lower extremity. A front-wheeled walker was used as an assistive device. A problem list was made and included: 1) Lacerations to right lower extremity, 2) Necrotic tissue present, 3) Edema, 4) Decreased ROM in the right lower extremity. Goals were set and included: 1) Decrease edema with elevation, increased weight bearing, and increased ROM, 2) Debride sloughing tissue as needed, 3) Increase ROM with weight bearing and therapeutic exercise, 4) Patient to be independent with therapeutic exercise, weight bearing, and gait. The treatment plan was to see the patient on a daily basis for whirlpool, therapeutic exercise, ROM, patient education, debridement, and dressing changes. On the day the evaluation was performed, the patient was treated in the Hubbard tank for twenty minutes and the wound bed was lightly cleaned with a 4x4 while the leg was immersed in the water.

Treatment/Intervention

The patient arrived the day after the initial hydrotherapy evaluation was performed ambulating with a cane. At this time, the patient had been discharged from the hospital and was being seen as an outpatient by hydrotherapy. For the first five treatment sessions, the patient was treated for twenty minutes in the Hubbard tank and the wound was dressed with SoftSorb pads or Xeroform, an ABD pad and burn net. Range of motion exercises and heel cord stretches were
also initiated at this time. It was noted that the entire flap of skin, which had been surgically reattached after the accident, was becoming necrotic. It was decided by the plastic surgeon after the first five treatments that maggot therapy would be initiated to prepare the wound bed for the STSG to be performed at a later date. Prior to applying the maggots, the plastic surgeon debrided the middle portion of the black, necrotic flap of skin to allow room for the placement of the maggots. The necrotic borders of the wound were left alone so that the healthy surrounding tissue would not be damaged. The maggots were used for a total of four treatment sessions and were replaced every third day or every 48 hours. The maggots were inserted into the wound bed via saline soaked 4x4s. The netting was secured with hypa-fix tape, and then an ABD pad for collecting drainage, and burn net were put into place. The patient and his spouse were instructed on the proper care of the maggots, how to change the top dressing (ABD and burn net), and on the signs and symptoms of infection. During the treatments with maggots, there were some complaints by the patient that the dressing design was not containing the maggots and that there was an increase in odor. He also noted that he could feel the maggots crawling around on his healthy tissue.

After the fourth treatment with maggots, hydrotherapy was discharged secondary to the patient checking into the hospital for a second time. At this time the patient complained of a fever (102 °F), fatigue, chills, and shivers. His platelets were elevated secondary to the inflammatory/infection phase reaction and blood cultures were positive for *Staphylococcus aureus, Pseudomonas aeruginosa* (multi-drug resistant), and *Serratia*. It was necessary to change the
type of antibiotics at this time from Piperacillin to Ampicillin Sulbactam and then finally to Meropenem to kill the infection. The day the patient checked into the hospital, he was kept on bed rest with the lower extremity elevated and was only allowed bathroom privileges. A hydrotherapy re-evaluation was performed on September 18, 1998, the day the patient was re-admitted to the hospital.

The re-evaluation noted the size of the entire wound bed was 27 x 14 cm. The odor was fowl and there was 20% necrotic tissue and 80% granulation, although the granulated tissue was not a good color. The color of the wound was deep red/purple granulation with yellow/gray slough. Brownish purulent drainage was present. Edema was noted on the right medial and distal lower leg. ROM and sensation were not tested however the patient was assessed for crutches. Two new goals were set, 1) Accelerate healing process, 2) Monitor for infection. All of the maggots were removed and the wound was dressed with a wet to dry gauze dressing, Kerlix roll, and burn net.

The day after the patient was admitted to the hospital with the infection and the re-evaluation was completed, hydrotherapy was continued. The patient was put in the Hubbard tank for twenty minutes and the wound was dressed with a wet-to-dry dressing, Kerlix, and burn net. Three days after the infection, a STSG was performed. There was 90% granulation in the wound bed prior to the graft being performed because it is important to have a clean, red wound with good circulation in order for the graft to take. The skin graft was taken from the anterior and lateral surface of the patient’s right thigh and was then placed on the open wound of the calf. A porcine xenograft (pig skin) was then placed on the
donor site of the thigh. Extra pieces of the graft taken from the thigh that were not used were stored in a refrigerator in case portions of the graft did not take. The graft and donor site were left open to the air after the surgery and a mixture of rosewater and glycerin were sprayed onto the sites to keep them moist. The patient was instructed on “rolling” the sites with Q-tips to rid it of pus and to keep the graft level. The patient was on bed rest post-operatively.

Two days after the STSG, the patient was seen by physical therapy for heel cord stretches, upper extremity blue thera-band exercises, and a footboard was put into place at the end of his bed to maintain the right foot in neutral. Three days after the STSG was performed, the patient was placed in the Hubbard tank again with no agitation for twenty minutes and then blotting was performed with a 4x4. The patient also began ambulation in hydrotherapy at this time. Six days after the graft was performed, it was necessary for the plastic surgeon to debride some areas of the wound where the graft did not take. The remaining tissue graft that was stored in the refrigerator was re-applied to the debrided areas. The newly re-applied grafts did not take because it was felt that they were left in the refrigerator for too long. Although the graft did not take in certain areas of the wound, the wound managed to heal on its own.

The remaining treatments in hydrotherapy included the Hubbard tank for twenty minutes, debridement with either a 4x4 or scissors and forceps, and dressing of an ABD pad and burn net. Eventually tubi-grip was used to help control any edema that was present. Prior to discharge from hydrotherapy, the wound measured 19.6 cm x 13 cm with good granulation present and migration.
from the edges of the wound bed. The patient was discharged from physical therapy services at this time and was to continue with his plastic surgeon.

Table 2 includes a summary of the subject's treatments and events from the time of the accident through to the time of discharge from physical therapy/hydrotherapy.

**Table 2. Summary of the client's medical treatments and events**

<table>
<thead>
<tr>
<th>DATE</th>
<th>TREATMENTS/EVENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/30/98</td>
<td>Accident occurred</td>
</tr>
<tr>
<td>9/3/98</td>
<td>Initial Hydrotherapy evaluation</td>
</tr>
<tr>
<td>9/3/98 to 9/9/98</td>
<td>Hubbard tank x 20', SoftSorb dressing or Xeroform with ABD, burn net, ROM exercises, heel cord stretches</td>
</tr>
<tr>
<td>9/4/98</td>
<td>Patient discharged from hospital, outpatient status</td>
</tr>
<tr>
<td>9/9/98 to 9/17/98</td>
<td>Maggot debridement therapy</td>
</tr>
<tr>
<td>9/18/98</td>
<td>Patient presents with infection and PT re-evaluation</td>
</tr>
<tr>
<td>9/19/98 to 9/21/98</td>
<td>Hubbard tank x 20', wet→dry dressing, Kerlix roll, burn net</td>
</tr>
<tr>
<td>9/21/98</td>
<td>Split-thickness skin graft (STSG)</td>
</tr>
<tr>
<td>9/23/98</td>
<td>Heel cord stretches, U/E exercises with blue theraband, footboard on bed put in place</td>
</tr>
<tr>
<td>9/24/98 to 10/19/98</td>
<td>Hubbard tank x 20' or whirlpool x 20', debridement with 4x4 (blotting) or scissors and forceps, Kerlix, liquid Elase, ABD, net, Santyl, Tubi-grip, &quot;over the counter&quot; Jobst (knee-high), ambulation, heel cord and hamstring stretches</td>
</tr>
<tr>
<td>9/26/98</td>
<td>Discharge from hospital, outpatient status</td>
</tr>
<tr>
<td>9/27/98</td>
<td>Areas of graft debrided and additional skin graft applied</td>
</tr>
<tr>
<td>10/19/98</td>
<td>Discharged from PT</td>
</tr>
</tbody>
</table>
CHAPTER IV

RESULTS

The history of maggot debridement therapy, biology, mechanisms of wound debridement, indications and contraindications of use, clinical application, dressing design, and the advantages and disadvantages were determined through the review of several journal articles and personal interviews.

The patient included within the case study responded well to different treatment techniques implemented and was seen approximately one and a half months by hydrotherapy for a total of thirty-four treatment sessions. The total cost of treatment in hydrotherapy was approximately $6,005.00 and costs included one evaluation, one re-evaluation, Hubbard tank, whirlpool, semi-selective debridement, and selective maggot debridement therapy.

To record this patient’s progress in hydrotherapy, measurements of the wound bed were recorded. The amount of tissue granulation and necrosis were recorded before the split-thickness skin graft (STSG) was performed. Table 3 shows how the four sessions of maggot therapy helped increase the amount of granulated tissue and decrease the amount of necrotic tissue and slough to help prepare the wound for the STSG. Table 4 shows the wound measurements taken during the initial evaluation, the re-evaluation, and at the time of the patient’s discharge.
Table 3. Percentages of necrotic and granulated tissue throughout hydrotherapy

<table>
<thead>
<tr>
<th>Date</th>
<th>% Necrotic Tissue and/or Slough</th>
<th>% Granulated Tissue</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/3/98 (Initial Evaluation)</td>
<td>Unable to assess</td>
<td>PTs unable to accurately assess at this time</td>
</tr>
<tr>
<td>9/6/98</td>
<td>Flap almost completely necrotic with some gray/white slough</td>
<td></td>
</tr>
<tr>
<td>9/14/98***</td>
<td>50% Necrotic</td>
<td>50% Granulation</td>
</tr>
<tr>
<td>9/15/98***</td>
<td>50% Yellow/gray slough</td>
<td>50% Granulation</td>
</tr>
<tr>
<td>9/17/98***</td>
<td>30-40% Yellow adherent slough, remaining is necrotic</td>
<td>&gt;40% Granulation</td>
</tr>
<tr>
<td>9/18/98 (Re-evaluation)</td>
<td>20% Necrotic with yellow/gray slough</td>
<td>80% Granulation</td>
</tr>
<tr>
<td>9/19/98</td>
<td>20% Slough</td>
<td>80% Granulation</td>
</tr>
<tr>
<td>9/21/98 (Day of STSG)</td>
<td>10% Slough</td>
<td>90% Granulation</td>
</tr>
</tbody>
</table>

***Patient received Maggot Therapy from 9/9/98 to 9/18/98

Table 4. Wound measurements throughout hydrotherapy treatment

<table>
<thead>
<tr>
<th>Date</th>
<th>Hydrotherapy Wound Measurements (length x width) in Centimeters</th>
</tr>
</thead>
</table>
| 9/3/98 Initial PT evaluation | 3 separate lacerations  
  ▪ medial proximal = 2 x 4.2 cm  
  ▪ medial distal = 11 x 1.8 cm  
  ▪ most lateral = 27 x 4 cm |
| 9/18/98 PT re-evaluation    | 27 x 14 cm                                                       |
| 10/16/98 Discharge from PT  | 19.6 x 13 cm                                                     |
A total of four sessions of maggot therapy were applied over a span of eleven days. An increase in the amount of tissue granulation was increased from 50% to 90% in approximately eight days. Four days after maggot debridement therapy was complete, the wound bed was at 90% granulation and the wound bed was ready for the skin graft surgery.

Figures 5 through 11 illustrate the wound's progression from September 4, 1998 to October 16, 1998, the time of discharge from hydrotherapy.

Figure 4. September 4, 1998 (five days after the bear attack). [The flap is sutured and three separate lacerations are present. The medial proximal laceration measures 2x4.2 cm, the medial distal laceration measures 11x1.8 cm, and the lateral laceration measures 27x4 cm].
Figure 5. September 8, 1998 (nine days after the attack). [One day before wound debrided in preparation for maggot debridement therapy. Maggot therapy initiated on September 9, 1998].

Figure 6. September 12, 1998 (thirteen days after the attack). [After one session of maggot therapy].
Figure 7. **September 14, 1998** (fifteen days after the attack). [After two sessions of maggot therapy, there is 50% granulation and 50% necrotic tissue present. The silvery-slimy tissue left behind by the maggots is visible].

Figure 8. **September 17, 1998** (eighteen days after the attack). [After three sessions of maggot therapy, there is greater than 40% granulation and 30 to 40% slough (the remaining is necrotic). The wound bed has good blood supply. Wound measures 27 x 14 cm].
Figure 9. September 29, 1998 (thirty days after the attack). [The STSG was completed on September 21, 1998. Additional graft was placed over areas of the leg that did not take on September 27, 1998].

Figure 10. October 16, 1998 (forty-seven days after the attack). [Wound bed measures 19.6 x 13 cm and graft is healing nicely. Patient discharged from hydrotherapy services on October 19, 1998].
CHAPTER V
DISCUSSION

To better understand the concept of maggot debridement therapy (MDT), it was first necessary to learn about the history of use, certain biological processes, and clinical applications. This background information aided in the process of reviewing the client's chart for the case study. By having a better understanding of the history, biology, mechanisms of wound healing, indications/contraindications, dressing design, advantages/disadvantages, clinicians can better explain it to their patients and appear, as well as feel, more confident with treatment sessions.

The subject responded well to MDT two years ago in preparation for the soft tissue skin graft to his right lower leg. The amount of time in therapy was minimal when compared to several studies involving stubborn non-healing ulcers. The client was compliant with his treatment sessions, exercises, and stretches and he consented to MDT. The problem of infection did arise and delayed the healing process, as was expected by the physician. The wound's progression was monitored through measurements (length x width), percent granulation and necrosis, tracing onto a plastic grid, and with photographs. Photographs are an excellent way to monitor changes and they not only show changes in size, but in color too. When using photographs, it is important to include an identification marker located next to the wound. The marker is made by taping a plastic
measuring sheet to a 3x5 card and then placing the card inside of a plastic sandwich bag. On the outside of the bag, the patient’s identification, date, and location of wound can be written on a white tape to stick on the outside of the bag. Once the photograph is taken, the bag can be thrown away but the 3x5 card is used again. Today, digital cameras exist that have computer software that performs the wound measurements as well as color monitoring. For uniform recording, it is important to keep the same distance from the camera to the wound. In this case study, the photographs do not have a measuring sheet located next to the wound in the photograph. This particular facility takes their pictures with a digital camera and then the images are saved on a computer. The measurements are taken with a disposable ruler and the measurements are recorded. I think that it is a good idea to have a measuring sheet in every picture because it is easier to compare photographs at a glance rather than having to look at measurements on another sheet.

Certain assessment tools are available to monitor wound healing such as the Sussman Wound Healing Tool (SWHT) and the Pressure Sore Status Tool (PSST). The SWHT was developed to track the effectiveness of physical therapy technologies used for pressure sore ulcers. This tool is composed of two parts including ten tissue attributes and nine descriptive attributes of size. This tool was found to be reliable and clearly shows wound progression or risk. The documentation is simple and it is easy to use, taking approximately five minutes. This tool could be modified to include the type and amount of granulated or necrotic tissue, amount of slough, presence of odor, and if edema is present.
The Pressure Sore Status Tool (PSST) is another tool that should be considered as an assessment tool and it was found to be valid.\textsuperscript{50} It is composed of 15 items that are scored from 1 to 5, except for size and location. The PSST appears to cover almost all areas of wound care and therefore would be helpful in the clinic, however both the SWHT and the PSST could be combined into one unique form. When using an assessment tool or if composing your own, important components should include: name, medical records number, examiner's name, dates, size (area), shape, depth/stage/edges, necrotic tissue (type, amount, slough), exudate (type, amount, odor, infection), granulation, contraction, undermining, epithelialization, color, edema, induration, maceration, hemorrhage, location (human body diagram to draw on), risk of skin breakdown, and the wound healing phase.\textsuperscript{48-50}

An assessment tool, such as the SWHT and the PSST, were not used for the patient included within the case study. Although both of these tools are designated for pressure sores, it is felt that either, or a combination of both, could be used in a facility for any type of wound, even those including traumatic injuries.

No studies with the use of MDT for a wound secondary to a bear attack could be located and most of the other studies reviewed involved patients with pressure sores, diabetes, or other debilitating conditions. One study of a 75-year-old man suffering from lymphostasis was located.\textsuperscript{2} Gangrene developed on his left leg below the knee and the wound was infected with \textit{Streptococcus aureus}. The infection remained even after surgical debridement and disinfection.
were performed. A skin graft could not be performed with the infection so MDT was initiated five days a week with the maggots left in place for 24 hours. Within two weeks, the entire infected area was clean and granulated tissue was present. After MDT was complete, the patient was referred for his autologous skin graft. Although this patient was older and more debilitated than the patient in this case study, the maggots cleansed the wound in two weeks and prepared the leg for a skin graft. The maggots in both cases were successful in preparing an infected lower leg wound for a skin graft in approximately the same amount of time.

Limitations to this study are that the problem of infection, as anticipated by the patient's doctor, did arise and may have delayed the patient's healing time. The plastic surgeon who treated this patient retired recently and was not able to be contacted for questions. Another limitation was that the initial evaluation measured three different lacerations, whereas the final discharge note measured the entire open wound remaining after the STSG. This made it hard to compare the initial evaluation to the patient's final discharge note from hydrotherapy, therefore progression was more easily noted by comparing the percent of tissue necrosis and granulation. The percent of tissue granulation and necrosis were not recorded on the first day of maggot debridement therapy (9/9/98) or on the second session of maggot therapy (9/12/98), making it hard to analyze the gains made with the maggots. No specific studies on a patient with a bear attack who received MDT was located and therefore it was difficult to compare this study's results to another resource. One final limitation to the study is that the wound bed was debrided by the plastic surgeon before the application of the maggots.
and therefore the photographs make it look like the maggots debrided an exceedingly large amount of necrotic tissue.
CHAPTER VI

CONCLUSION

Maggot debridement therapy (MDT) has been used as a form of wound treatment since the Civil War. The species of fly used today is Lucilia sericata or Phaenicia sericata, and a majority of wound types treated includes ulcers, pressure sores, and traumatic injuries. The history, biological processes, and clinical use researched in this study are important for clinicians to understand when using MDT. This background information, in the form of a literature review, is presented in one concise resource and will be useful for those clinicians already using MDT in the clinic or for those clinicians or students who are interested in considering their use. The case study included presents how MDT was used after a traumatic accident to prepare an infected wound for a split-thickness skin graft. Good results were achieved in what is felt was a minimal amount of time. The Wyoming facility protocol presented will allow other departments using MDT to compare their own protocol with the one presented here and to evaluate its effectiveness.

The method of clinical application is one of trial and error and can depend on the supplies available in the clinic. The dressing design should be “cage-like” in order to contain the larvae. Patients need to be prepared for this type of therapy and therefore should have a thorough explanation before their treatment.
begins. It is felt that the advantages outweigh the disadvantages and that this form of treatment can be used for many different cases. It has been felt that if MDT were used earlier in treatment, rather than as a last resort treatment, that even greater gains could be made in healing. This earlier application of maggots would prevent the need for topical or systemic antimicrobial treatment. If maggots have been effective enough to treat patients who otherwise may have lost limbs despite antibiotics and surgery, than we should use maggots before wounds progress that far. Clinical studies at the Veteran Affairs Medical Center and at the University of California are still underway, however they have already shown that MDT is more effective at cleaning infected and gangrenous wounds than any other non-surgical treatment and that they clean wounds in a shorter amount of time. With shorter treatment times, maggot debridement therapy can be considered cost-effective. Through the years the amount of coverage for patient treatments has decreased therefore presenting a challenge for physical therapists as well as other healthcare workers in providing treatments that are more effective. With shorter healing rates, the treatment costs for patients, as well as insurance agencies, will be less. If maggots are unable to initially be used as a treatment, than they should at least be considered for use in conjunction with other wound care methods.
APPENDIX
EXPEDITED REVIEW REQUESTED UNDER ITEM ____ (NUMBER(S)) OF HHS REGULATIONS

X EXEMPT REVIEW REQUESTED UNDER ITEM ___ (NUMBER(S)) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM
FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED
PROJECTS INVOLVING HUMAN SUBJECTS

Please include ALL information and check ALL blanks that apply.

PRINCIPAL INVESTIGATOR: David Reiling, Leslie Mayer

TELEPHONE: (701) 777-2831  DATE: 4/24/00

UND Dept. of Physical Therapy
University of North Dakota
501 N. Columbia Road
P.O. Box 9037
Grand Forks, ND 58202-9037

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT:

SCHOOL/COLLEGE: A&S, Medicine  DEPARTMENT: Physical Therapy


PROJECT TITLE: "Considering the Use of Maggots in the Debridement of Wounds: a case study"

FUNDING AGENCIES (Include copy of proposal): None

TYPE OF PROJECT (Check ALL that apply):

NEW  X PROJECT  CONTINUATION  RENEWAL  DISSERTATION OR THESIS RESEARCH  X STUDENT RESEARCH PROJECT

CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: David Reiling PT, MS

PROPOSED PROJECT:  X INVOLVES NEW DRUGS (IND)  INVOLVES NON-APPROVED USE OF DRUG  INVOLVES A COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATION, PLEASE INDICATE THE CLASSIFICATION(S):

☐ MINORS (<18 YEARS)  ☐ PREGNANT WOMEN  ☐ MENTALLY DISABLED  ☐ FETUSES  ☐ PERSONS WITH MENTAL RETARDATION

☐ PRISONERS  ☐ ABORTUSES  ☐ UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE

IF YOUR PROJECT HAS BEEN WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S), PLEASE LIST NAME OF BOARD(S): Will be submitted to the Wyoming Medical Center in Casper, WY

Status: Submitted  Date:  Approved  Date:  X Pending

1. ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.)

Maggot Therapy is a form of wound treatment in which several sterile maggots are placed inside of a non-healing wound. The maggots help to promote healing by cleansing the wound and controlling infection. Several studies have been made concerning maggots and several show that maggots promote healing faster than other forms of wound therapy. The purpose of this project is to gain a better understanding of the biological processes of how maggots aid in the healing of wounds. The history of maggot use, the biological properties, clinical use and methods of application, and future trends will be reviewed. In addition to the literature review, a case study from a patient who has received this type of treatment will be included. The information from the case study will be obtained through a chart review from the Wyoming Medical Center in Casper, WY where this treatment is performed. It will be important to include an actual case study from this particular facility because I would like to determine gains made with maggots at a Wyoming facility. None of the studies I have reviewed have involved this Wyoming facility.
PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary. Attach any surveys, tests, questionnaires, interview questions, examples of interview questions (if qualitative research), etc., the subject will be asked to complete.)

A chart of a patient who has already received treatment at the Wyoming Medical Center will be reviewed for this study. The study protocol will involve reading through several charts of past patients and then selecting one chart to include in my study. The patient will have already undergone maggot therapy for debridement/cleansing of a wound, therefore the treatment is not experimental.

3. BENEFITS: (Describe the benefits to the individual or society.)

There are several benefits to this study. First, and most importantly, the client or patient benefits. Maggot therapy is generally pain free, takes fewer treatment sessions, and often the odor associated with wounds is significantly reduced. Second, society benefits because if its effectiveness is proven its use will gain acceptance and wounds can be treated in shorter amounts of time. With a decrease in healing time there will be lower bills and money spent in wound care facilities. Finally, maggot therapy benefits the profession of physical therapy. It will improve the knowledge of students and practitioners by making them more aware of positive results made in wound care. With increased awareness of their use, more and more healthcare workers may consider using maggots in wound care. By having access to this study, other students may develop research projects through the information presented. More and more facilities are using maggots today, however I feel that further studies are necessary in proving their positive results and to gain their acceptance nationwide.

4. RISKS: (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psychological, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, debriefing procedures, storage of data for the required three years, final disposition of data, etc.

Since this study is a chart review only and no actual procedures will be performed, there are no physical risks. One risk of this study involves patient confidentiality. By performing a chart review, I will have access to the patient's name, any procedures performed, and their medical number. The correct steps will be taken regarding patient confidentiality. The patient's name and medical number will be blackened out on any copies made from their medical chart. The patient's name and medical number will not be included in the study in any form. Any information used for this study will be kept in a locked filing cabinet in the physical therapy department at the University of North Dakota where it will destroyed after 3 years. I have contacted the Wyoming Medical Center and we have discussed the necessary paperwork needed to be completed in order to obtain information on a past patient who has received maggot therapy. The necessary paperwork will be completed concerning access to patient charts and confidentiality issues.

5. CONSENT FORM: Attach a copy of the CONSENT FORM to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no CONSENT FORM is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

Describe where signed consent forms will be kept for the required 3 years, including plans for final disposition or destruction.

No consent forms will be used in this study because the treatment with maggots has already been performed.
6. For FULL IRB REVIEW forward a signed original and fifteen (15) copies of this completed form, including fifteen (15) copies of the proposed consent form, questionnaires, examples of interview questions, etc. and any supporting documentation to the address below. An original and 19 copies are required for clinical medical projects. In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency should be attached to the completed Human Subjects Review Form if the proposal is non-clinical; 7 copies if the proposal is clinical medical.

Office of Research & Program Development  
University of North Dakota  
Grand Forks, North Dakota 58202-7134

On campus, mail to: Office of Research & Program Development, Box 7134, or drop it off at Room 105 Twamley Hall.

For EXEMPT or EXPEDITED REVIEW forward a signed original, including a copy of the consent form, questionnaires, examples of interview questions, etc. and any supporting documentation to one of the addresses above. In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency should be attached to the completed Human Subjects Review Form.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:

Principal Investigator

Project Director or Student Adviser

Training or Center Grant Director

(Revised 4/1998)
REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

Date: May 31, 2000
Project Number: IRB-200006-229

Name: David Reiling, Leslie Mayer
Department/College: Physical Therapy
Project Title: The Use of Maggots in the Debridement of Wounds: A Case Study

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on June 6, 2000 and the following action was taken:

☐ Project approved. EXPEDITED REVIEW Category No. 
Next scheduled review is on:

☐ Project approved. EXEMPT REVIEW Category No. 4
No periodic review scheduled unless so stated in the Remarks Section.

☐ Project approved PENDING receipt of corrections/additions. These corrections/additions should be submitted to ORPD for review and approval. This study may NOT be started until final IRB approval has been received. (See Remarks Section for further information.)

☐ Project approval deferred. This study may NOT be started until final IRB approval has been received. (See Remarks Section for further information.)

☐ Project denied. (See Remarks Section for further information.)

REMARKS: Any changes in protocol or adverse occurrences in the course of the research project must be reported immediately to the IRB Chairperson or ORPD.

PLEASE NOTE: Requested revisions for student proposals MUST include adviser's signature.

cc: David Reiling, Adviser
Chair, Department of Physical Therapy
Dean, School of Medicine

Signature of Designated IRB Member
Date
UNO's Institutional Review Board

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact ORPD to obtain the required documents.

1/98
RELEASE STATEMENT

I hereby give my permission to the University of North Dakota, its agents, successors, assigns, clients and purchasers of its services and/or products, to use information from my medical chart that is pertinent to this research project. I also give my permission for the release of any photographs (whether still, motion or television) that were taken in hydrotherapy. I understand that steps will be taken concerning patient confidentiality and that my medical number, name, and the name of the health facility will not be used. I also understand that my face will not be included in any photographs used.

Name:

Signed:

Date:

Address:

City:

State and Zip code:
REFERENCES


36. RA Sherman [rsherman@uci.edu], email, 10/16/00.


