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DESIGN OF A KNEE IMMOBILIZATION EQUIPMENT: FACING MULTIDISCIPLINARY CHALLENGES FROM BOTH ENGINEERING AND PHYSIOTHERAPY FIELDS

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Abstract. *The number of accidents that result in fractures and/or dislocations of the knee, especially when dealing with traffic accidents, has grown at an alarming rate in Brazil. The statistics released by DPVAT (Brazilian insurance company for traffic accidents) confirm the number of accidents growth and has shown that in 2014, it was paid about 763.365 applications claim for compensation. On the way to work or school, it is increasingly more common to come across unpleasant scenes of people lying on the asphalt after facing a motorcycle accident and presenting multiple fractures. Unfortunately, rescuers professional of ambulances do not yet have available any effective equipment for immediate immobilization of an injured leg. In this situation of emergency, they end up calling for immobilization methods quite rustic and primary, using cardboard, bandages or any other utensil that is within reach to make a slow, fragile and inappropriate immobilization. Assuming the existence of fractures in the knee region and that the importance of quickness is inherent to any Emergency Medical Assistance (EMS) activity, it is essential that the leg remains exactly at the same fracture position until the patient reaches the hospital. A simple movement can increase the risk of an irreversible damage to the patient, reaching levels of complications that can mean from the total loss of movement to even an amputation of the limb. There is a consensus among health professionals about the need to seek to develop a lightweight equipment, easy to use and, above all, effective to ensure both speed and robustness of the practice of immobilization. In this context, this article presents a new concept of design of a prototype device that overcomes the various challenges mentioned above. In this article, the main contributions of an entire multidisciplinary team (i.e. engineers, physiotherapists, etc.) are described along with the excellent results achieved in the preliminary practice tests carried out in street field trials. Finally, the relevant conclusions are presented.*

Keywords: *Knee immobilization, Prehospital equipment, System Engineering, Bioengineering, Prehospital care, EMS*

1. INTRODUCTION

Several vectors add up to explain the high number of accidents that culminate in dislocations and or knee fractures in Brazil. For example, the statistical data released by the National Department of transit (DENATRAN) show that between 2001 and 2011 the fleet of motorcycles increased in the order of 300% and reached the mark of 18,442,413 units in circulation. In those 10 years, the number of deaths in traffic accidents with two-wheeled vehicles increased almost in the same proportion reaching alarming digit of 263%. According to the Ministry of health, the cost of hospitalization in 2011 was of US$ 30 million only for the motor bikers.

Later, in mid-2013, new statistics, this time disclosed by the insurance company called Líder (i.e.DPVAT), pointed out that accidents involving motorcycles accounted for 75% of all claims paid in the first half of the year (256,387 severance payments). Motorcycles led the statistics in 2013. Finally, a good number also disclosed in the current page of the insurance company DPVAT, shows that in 2014 around 763,365 compensation claims applications were paid (i.e. including all types vehicles and pedestrians).

All figures presented are very important for the context of this work and to a deeper reflection of the situation and the challenges to overcome. Thus, although the various types of accidents and, more specifically, those involving motorcycles, can cause head injuries and skull-brain injury, nerve damage, open fractures and multiple fractures, the focus of this article is directed only to cases with dislocations and/or knee fractures due to the very nature of the equipment to be designed. As an extension, the proposed device may also work immobilizing both femur and tibia fractures.

2. THEORETICAL FUNDAMENTALS

It is known that ambulances worldwide are outfitted with effective equipment for immediate immobilization of a knee injury (Pickering *et all*, 2009) (Bell, 2012) (Lee *et all*, 2013). In Brazil, the paramedics end up calling for immobilization methods quite rustic and primary, using cardboard, bandages or any other utensil that is within reach to make a slow, fragile and inappropriate immobilization (MS,2002).

The time spent in pre-hospital care in emergencies has great importance, both to save lives, as well as to ensure that injuries and trauma can be treated without generating significant sequelae in the future. In the United States, since 1996, the "Committee on Trauma of the American College of Surgeons" (CTACS, 1996) established the time of twenty minutes as maximum range ideal for implementing the first procedures, in severe cases. Thus, the American standard corresponding to 1710 standard of the National Fire Protection Association-NFPA (National Fire Protection Association) has set as a goal that 90% of requests for help in the urban area are met in a maximum of 480 seconds (08 minutes). However, local laws in several states/counties in the United States adopt the optimum time of ambulance for pre-hospital care as of 08 minutes and 59 seconds in an urban area, 15 minutes in rural area and 30 minutes in an area of dense forest. The Brazilian numbers regarding response time to pre-hospital care vary greatly from city to city, but studies done by (Minayo,2008) (Silva,2012) in six state capitals show that in none of them the average total time is less than 20 minutes.

It is consensus among health professionals the need for the market to design an innovative lightweight easy-to-use equipment and, above all, effectively guaranteeing both quickness and robustness in the practice of immobilization. In addition, health authorities already face several factors that make it difficult to achieve the goal of the optimum time of ambulance for pre-hospital care (i.e. traffic jams, insufficient number, reduced staff, etc.). Consequently, the equipment presented in this paper intend to be a contribution to an effective immobilization and to help minimize the time of pre-hospital care in cases of fractures of knee. Its design was based on appropriate research methods found in the literature.

3. AMBULANCES OF BRAZILIAN EMS: MINIMAL EQUIPMENT, SUPPLIES AND RESPONSE TIME

The dimensions and other constructive specifications to manufacture ambulances must always comply with the Brazilian standards of engineering, in particular to the NBR 14561/2000 of the **B**razilian **A**ssociation of **T**echnical **S**tandards. However, there is an Ordinance of the Ministry of Health number 2048, (MS,2002) approving the Technical Regulation of the State of emergency and emergency Systems in which a complete list by specifying a minimum set of equipment to be fitted on various types of ambulances. Ambulances are part of the Brazilian Mobile Emergency Care Service – **SAMU**- officiated by Ministry of health by means of Decree number 5,055 from 2004. There are several types of ambulances as defined in Ordinance: AT-Ambulance for transport, ASB-Basic Support ambulance, AR-Ambulance for Rescue, ASA-Ambulance for Advanced Support and ATM-Medical Transport Aircraft. In addition to classical, there are other vehicles ambulances called by Ordinance as "Rapid Intervention Vehicles". Following is the minimum list of equipment required in the most common type of Brazilian ambulance (ASB -Ambulance for Basic Support):

1)optical and acoustic flag; 2) radio equipment for both landline and mobile communications; 3) articulated and wheeled gurney; 4) support for serum; 5) oxygen network installation with cylinder, valve, pressure gauge in place of easy visualization and ruler with double outlet; 6) oxygen with triple ruler (i.e. feeding respirator; flowmeter and oxygen humidifier; Venturi vacuum cleaner.) 7) gauge and flowmeter with mask and whip for oxygenation; 8) portable oxygen cylinder with valve. Emergency bag containing: 9) adult and infant stethoscope; 10) manual resuscitator adult/child; 11) oropharyngeal tubes of varying sizes; 12) disposable gloves, scissors with blunt tips; 13) straight tape; 14) sphygmomanometer; 15) 15 cm bandages; 16) sterile compresses; 17) sterile gauze packages; 18) protectors for burned or eviscerated; 19) catheters for oxygenation and aspiration of various sizes. Delivery bag containing: 20) surgical gloves; 21) clamps; 22) sterile stylus for cutting umbilical cord; 23) plastic bag for placenta; 23) blanket; 24) surgical swabs; 25) sterile gauze; 26) identification bracelets; 27) support for serum. In addition to that: 28) short and long board for immobilization of spine; 29) splints for immobilization of members; 30) sets the cervical collars; 31) dorsal immobilizer vest; 32) bottles of saline and ringer's lactate; 33) triangular bandages; 34) reflective vests for crew; 35) hand lantern; 36) glasses; 37) masks and protective aprons; 38) suitcases with medications.

The ambulances of basic support, which perform rescue actions, should also contain the minimum material for terrestrial, aquatic rescue and, at times, tool bag and dry chemical powder extinguisher of 0.8 kg, tapes and signposted cones for areas isolation. Finally, they should provide an isolated compartment, ensuring a service to victims of at least 8 cubic meters. Keeping in mind that the focus of this article is directed to immobilization equipment, only some of the aforementioned kits (i.e. Immobilization equipment and fixing bandages) are illustrated in next subsection. However, for the illustration of a complete list, the reader can refer to the “Pre-hospital care manual” published by the Fire Department of Paraná State (CBPR, 2004).

3.1 Current immobilization equipment and fixing bandages

The main equipment used for immobilization available in the market and, sometimes, in ambulances are:

a) **Hinged splint of wood and cardboard splint -** Essential equipment used for dealing with the immobilization of fractures and dislocations;
b) **Triangular bandages and crepe bandages** – Used for fixation of splints and dressings;
c) **Belts** - flexible and resistant belts that are designed to hold the victim along the board of immobilization.

The splints, bandages and belts are illustrated in Fig. 3.1, below:

Figure 3.1. The splints, bandages and belts (Source Porcides,2006)

d) **Femur Traction Device -** equipment for the immobilization of the lower limbs, with closed fractures. Manufactured in aluminum or stainless steel, with length adjustment by means of tie rods and ratchet system. Figure 3.2 illustrates some of these devices. The rightmost one is the Kendrick Traction Device (KDT).

Figure 3.2- Femur Traction Devices

e) **KED - Kendrick Extrication Device** - Intended for the removal of victims from auto accidents that are still sitting, aiming the immobilization of the cervical spine, thoracic and upper lumbar. Used when the kinematics of the trauma and the signs and symptoms presented by the patient, during primary assessment, suspect column injury. For its correct application it requires the presence of three professionals, and the vest KED should be used in conjunction with the collar allowing the immobilization of the head, neck, cervical, dorsal and lumbar in an anatomical position, allowing the patient to be immobilized, extricated (i.e. removed) and transported in a sitting position, preventing additional injuries during the extrication maneuvers. Device includes wrap-around vest, Adjusta-Pad neck roll, and two head straps. Fix happens through fixed and mobile flexible rods.

Figure 3.3- KED - Kendrick Extrication Device(Source Porcides,2006)

f) **Cervical Collar -** Intended for immobilization of cervical column about the axial movements for those who have had traumatic head or neck injurie. It is made of polyethylene, foldable and available of various sizes and models
g) **Immobilization Board** - Equipment used for the immobilization of a victim lying. Are of various models and sizes, with openings for fixing belts and head immobilizers. (see Fig. 3.5).
h) **Head immobilizers -** Equipment used for the total immobilization of the victim's head. Made of foam covered with a waterproof and washable material.

Figure 3.4- Cervical Collar(Source Porcides,2006)

Figure 3.5- Immobilization board with head immobilizer

After introducing the various equipment available in ambulances, it is important to highlight that to immobilize dislocations and/or knee fractures there is available just splints, bandages, belts and femur traction device. That is true assuming that the ordinance of the Ministry of health number 2048 is respected in full and the equipment in ambulances are complete. However, in practice, the Brazilian authorities already recognize the shortcomings of the system and encourage the rescue team to use any object within reach, including umbrellas. Therefore within the ordinance explanatory section concerning different types of splints, it states: "*the professional must know how to improvise a splint from objects such as umbrellas, cane, wood clapboard, thick magazines, pillow, cardboard, folded, etc*."

3.2 Ambulance’s response time importance for pre-hospital care

In 2009, a team from the British NHS (National Health Service) published (Pickering *et all*, 2009) a comparative report between international best practices for emergency ambulance services. This report published the response time targets of various countries and compared, in terms of percentage, with the 480 seconds (i.e. 08 minutes) regulated in 1710 standard for the NFPA(National Fire Protection Association) in the US. Figure 3.6 illustrates the response time of ambulances in the various countries according to that report.

Figure 3.6 shows that the shortest response time found was in the city of Vantaa in Finland with only 52%, meaning 4 minutes and 10 seconds (i.e. 52% of the 08 minutes NFPA standard). The longest was verified in the city of Copenhagen in Denmark with 89%, meaning 7 minutes and 07 seconds (i.e. 89% of the 08 minutes NFPA standard). There are some specific laws in several states/counties in the USA that are a little more flexible and adopt the optimum time of ambulance for pre-hospital care as of 08 minutes and 59 seconds in an urban area, 15 minutes in rural area and 30 minutes in an area of dense forest. It also requires that 90% of the calls to be within that time adopted as goal

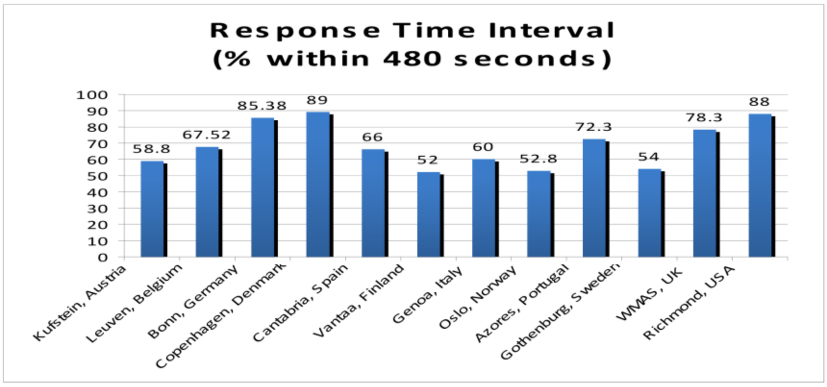


Figure 3.6- Ambulance response time in 12 countries best practices for EMS. Source (Pickering *et all*, 2009)

The response time of ambulance for pre-hospital care in Brazil is well above those found in the countries presented in Fig. 3.6. The numbers vary greatly from city to city. Studies done by (Minayo,2008) (Silva,2012) in six capitals show that in none of them the average total response time is less than 20 minutes. This data is very worrying, because according to "Committee on Trauma of the American College of Surgeons" (CTACS, 1996) the proper time is twenty minutes at the most ideal range for execution of the first procedures in severe cases. Beyond that time, the number of deaths only tends to increase after pre-hospital care.

4. DEFINING THE PROBLEM TO BE SOLVED

In case of accident, it is essential that the leg remain exactly at the same post fracture position until the patient reaches the hospital. A simple movement can increase the risk of an irreversible damage to the patient, reaching levels of complications that can mean from the total loss of movement to even an amputation of the limb. Whenever a leg/knee is fractured it is necessary to immobilize it. Fractures can be of either closed or exposed type. The closed ones match those in which the skin remains intact. Figure 4.1 shows, from left to right, five types of closed fractures: stable, transverse, spiral and comminuted. The last most right positioned in the illustration is called open fracture. It occurs when a bone breaks in such a way that bone fragments stick out through the skin or a wound penetrates down to the broken bone.

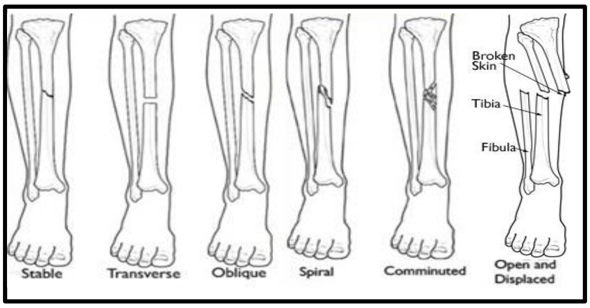
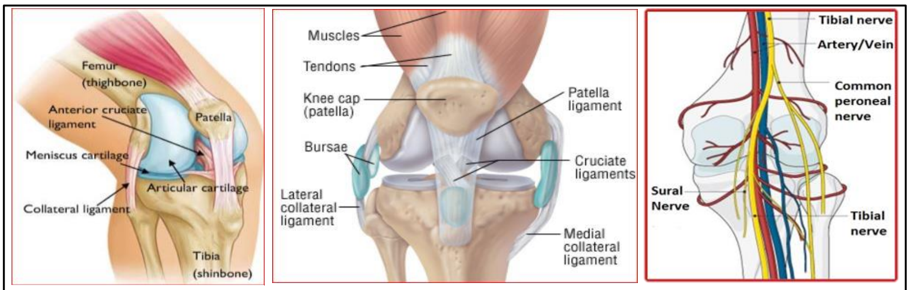


Figure 4.1-Fracture patterns (adapted from OEB, 2015a)

If one considers the case of very strong impacts, open fractures may cause a broken leg to turn to a weird reverse rotating position. This usually causes a very unpleasant and hard to see scenes for people who are not working in health care related field. However, no matter how strong is the scene of an accident, the paramedics must immobilize the lower limb members assuring to maintain exactly their post fracture angles and positions.

There are several reasons why one should not try to relocate a broken bone after a dislocation and/or fracture. Aiming a better understanding of why the requirement mentioned above is so important, the anatomy of the knee, albeit in a simplified form, is here introduced. The knee is a complex set of components that work in harmony, namely: bones, joints, ligaments, tendons, muscles, nerves and blood vessels. Bones and cartilages are shown are in Fig 4,2a. Ligaments, tendons and muscles are show in Fig, 4.2b. The knee joint has four major ligaments. The Medial Collateral Ligament (MCL) supports the knee along the inner side of the leg. The Lateral Collateral Ligament (LCL) supports the outer side of the knee. The Anterior cruciate ligament (ACL) and the posterior cruciate ligament (PCL) bridge the inside of the knee joint, forming an "X" pattern that stabilizes the knee against front-to-back and back-to-front forces. Figure 4.2c illustrates nerves and blood vessels (i.e. artery and vein) surrounding the knee joint and bones.



a) Bones and cartilages **b) Ligaments, tendons and muscles** **c) Nerves and blood**

Figure 4.2- The anatomy of the knee (Adapted from OEA, 2015b and HMS, 2015)

When a bone is fractured, its remaining fragments become sharp and may, dangerously, behave as real knives. These fragments and their sharp edges sometimes get in certain positions that, if the rescuer mistakenly tries to reposition the leg by stretching it, the fractured bones may end up tearing the soft tissues around the knee. It may also, cut and cause damage to a particular ligament, blood vessel and/or nerve. This could mean very bad news. It is known that the ligaments, for example, are very rich in sensitive nerve receptors and, therefore, are responsible for realizing about the speed, movement status, joint position and any stretching and pain. They transmit such information to the cerebellum that permanently responds with motor orders to the muscles. This important task is known as proprioceptive sensitivity.

What happens if the sciatic nerve is affected? The most important nerves around the knee are the tibial nerve and the common peroneal nerve in the back of the knee (see Fig. 4.2c). These two nerves travel to the lower leg and foot, supplying sensation and muscle control. The large sciatic nerve splits just above the knee to form the tibial nerve and the common peroneal nerve. The tibial nerve continues down the back of the leg while the common peroneal nerve travels around the outside of the knee and down the front of the leg to the foot. Finally yet importantly, is the risk of a cut in an artery or vein when one tries to move a fractured leg or due to an inappropriate immobilization. A cut of an artery may even be life threatening if the bleeding is not immediately stopped. For all these reasons, the immobilization of the knee needs to happen exactly on the resulting post fracture angular position found at the site of the accident. It needs to be fast, robust and effective by ensuring no further harm to the victim of the accident.

Once having clearly defined the problem, a team of mechanical engineers and physiotherapists aiming to face the above-mentioned multidisciplinary challenges carried out a research work to serve as foundation for a new concept of design packed with hybrid approaches to meet its complexity. The goal has become to seek the development a lightweight equipment, easy to use and, above all, effective to ensure both speed and robustness of the practice of immobilization.

5. MATERIALS AND METHODS

The R&D (Research and Development) work described here was based on a hybrid approach (see Fig. 5.1) combining both Systems Engineering methodology (SE) (PAHL,2005) and a structured PDP (Product Development Process) model known as "PDPNet process reference model" which was proposed by Rozenfeld, *et al.*, (2006).

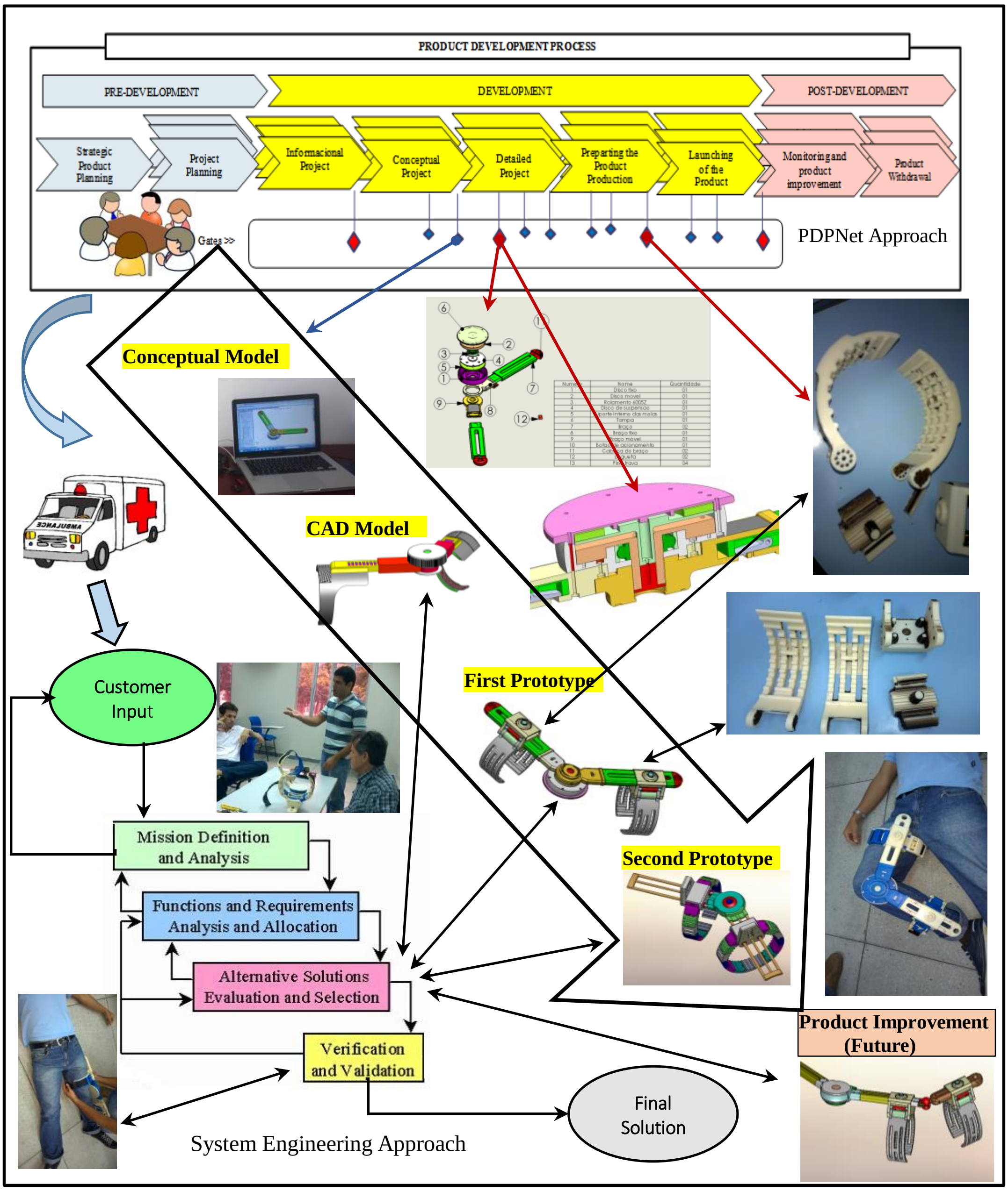


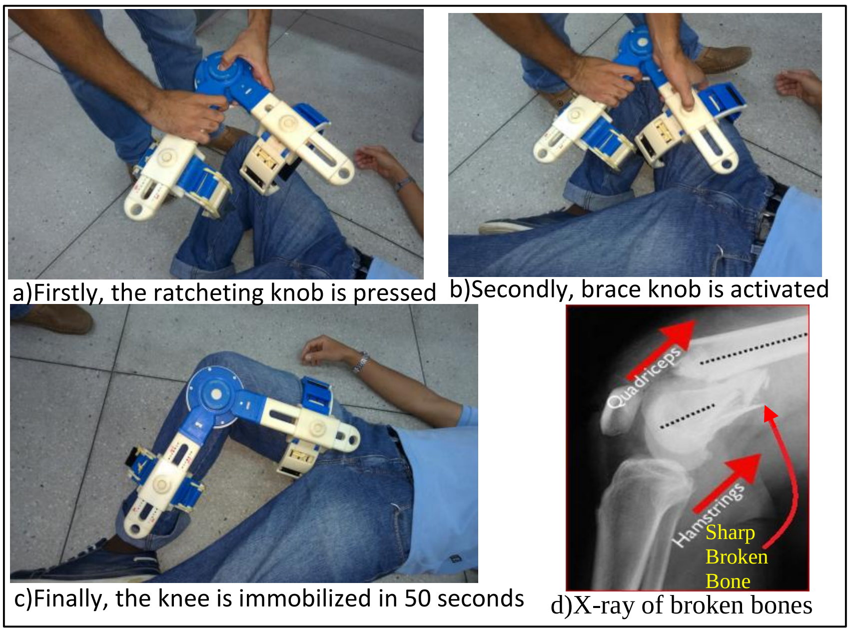
Figure 5.1- A hybrid approach combining both PDPNet and Systems Engineering methodologies.

Systems Engineering (SE) is a problem-solving methodology (planned procedure) for designing and configuring systems, especially those of a technical and complex nature. It comprises of six phases: problem analysis, problem formulation, system synthesis, system analysis system evaluation and system decision. On the other hand, PDPNet approach comes to meet the multidisciplinary bias and commercial side of the project in a way that is more appropriate. After all, the project was developed in collaboration with a local industry. The PDPNet approach is divided into three macro-phases: pre-development, development and post- development. Each macro-phase is divided into phases, activities and tasks. The Pre-development macro-phase is the link between the projects developed by the company and its goals. It includes the company’s strategic product planning, which involves the Corporation or Business Unit Strategic Plan deployments on project portfolio, with the evaluation and track of selected projects. The Development macro-phase includes the phases in the informational project, conceptual project, detailed project, preparation for production and product launching. All these phases entail detailing of technical, commercial and production information, involving elements such as technical drawings, prototypes, homologations, records, partnerships with suppliers and production processes. The information phase comprehends translation of the analysis of market and customer information into engineering specifications. Finally, during the Post-development macro-phase one performs the follow-up of product life cycle will assess the product performance in the market, its withdrawal and future improvement processes

The complete requirement checklist for the designed equipment is not illustrated but cannot be described in this paper due to lack of space. However, some important design requirements adopted were: a) size, height, length, diameter, space, connection and arrangement (i.e. geometry) b) direction of forces, magnitude, weight, load, deformation, stiffness, elasticity and inertia (i.e. forces); c) efficiency, friction (i.e. energy); d) washable, easy to transport, physical and chemical properties(i.e. Material); e) maximum permissible manufacturing cost, cost of tooling, material cost, time (i.e. Costs in general); f) time constraints, end date of development, project planning and control, delivery date (i.e. Schedule).

6. RESULTS AND DISCUSSION

The prototype of a knee immobilization equipment developed in this R&D project is show in figure 6.1(a, b and c). It must be highlighted here that not many design details are being published in this paper because the equipment is still undergoing a process of patenting. However, one can easily note that the immobilization procedure performed by this innovative equipment in now far much simpler and faster. It took only 50 seconds and proved to be a two steps easy task.



a)Firstly, the ratcheting knob is pressed b)Secondly, brace knob is activated

c)Finally, the knee is immobilized in 50 seconds d)X-ray of broken bones

Figure 6.1- The performance of the knee immobilization equipment and an X-ray of a broken bone.

The developed equipment weights 1.4 kg, is made by ABS plastic and comes in two different sizes: adult and child. It is washable and able to immobilize several angular configurations of post-fractured knees ranging from 0^{o} to 300^{0} degrees. It can be automatically locked at intervals of one degree at a time. Each scale division in the main ratchet is equal to 1 degree. This is an innovative feature, because none of the current existing devices available in the market is able to deal with this situation. Furthermore, the patient may stay in ventral, horizontal dorsal or in lateral decubitus position.

Although the equipment scope was mainly intended to deal with broken knees, if the bones are not broken in many pieces, it can also be used to immobilize the fractured femur and/or tibia. Actually, this limitation while dealing with more than one fracture is due to the limited amount of braces (i.e. just two: shin and thigh braces) available in the model. Figure

3.2 illustrates that femur traction devices available in the market have four elastic straps (i.e. ankle, shin, thigh and upper thigh) in order to stabilize the lower limbs. Their drawbacks concern the fact that these market models will no work if a leg is bending. They require any leg to be stretched.

The x-ray illustrated in figure 6.1d is a good example to explain why it could be a disaster if one mistakenly stretches that leg. The indicated sharp broken bone could tear off tissues and damage the tibial nerve or artery near that region (see Fig. 3.1c). The equipment designed in this research solved this problem by assuring the leg will be kept still in the post-fractioned position. One must bear in mind that the x-ray will not be available until the patient reaches the hospital and that no one can guess the broken bone scene invisible for naked eyes. Finally, there are two extra drawbacks to be pointed out: even when the equipment is positioned in 0^o degree angle (i.e. stretched leg) it provides no traction function. Furthermore, it should provide a support handle to be hung on rescuer's neck for easy transport and to prevent falls.

7. CONCLUSIONS

Whereas the focus of this research is the ambulance’s EMS (Emergency Medical Service) for covering accidents’ rescue, the following conclusions concerning the developed equipment, can be drawn from the results obtained so far:

a) The project was definitely innovative and has met the expectations and requirements imposed by the multidisciplinary team including mechanical engineers, physiotherapists, etc. The product, yet in prototyping mode, came to overcome many challenges so that it managed to significantly reduce the immobilization time of fractured knees;
b) The main innovation of this product relies on its possibility to perform the immobilization procedure in any position (i.e. lateral, ventral, etc.) while the leg may remain folded into angular positions of up to 300 degrees. No need to roll the patient, raise or stretch his leg. Its effectiveness, reduces the possibility of further vascular and nerve damage;
c) The most common femoral traction devices can be properly applied in approximately 600 seconds (average of 10 minutes) whereas the presented new product is 50 times faster running the same action in just 50 seconds. Even if one considers the case of modern Kendrick Traction Device(KTD), the reduction is of 240% (i.e. 120 down to 50 seconds). This is true, regardless of the fact that KTDs require the patient leg always stretched in linear position;
d) Due to the above-mentioned time reduction, this new product may be vital in helping the Brazilian EMS service to achieve international standards targets concerning ambulance’s response times. Even in countries that already have great pre-hospital care services, it can be a good ally. Furthermore, the Brazilian chaotic traffic associated with the lack of urban mobility plans which are only due in 2018 (Brazilian law 12587 issued in 2013) will reinforce the importance of any gain concerning response times.
e) Finally, it is important to mention that further steps towards the PDPNet approaches, in order meet the commercial side of the project and to possibly eliminate some of the equipment drawbacks, need to be addressed in near future.

8. REFERENCES

Bell, R. C., 2012. *The Ambulance: A History*. McFarland, London, Reprint edition.

CTACS, 1996. Committee on Trauma of the American College of Surgeons, “Hospital and prehospital resources for optimal care of the injured patient”. Bull Am Coll Surg., 71:4-23.

HMS, 2015. *Private Communication*. Harvard Medical School, H. Health Publications. 23 Jun 2015 <http://www.health.harvard.edu/pain/knee-sprain>

Lee, Y.T, Kibira, D., Feeney, A. B. and Marshall, J., 2013. “Ambulance Design Survey 2011: A Summary Report”. *Journal of Research of the National Institute of Standards and Technology*., Vol. 118 p. 381-395.

Minayo M C S, Deslandes S F., 2008. “Análise da implantação do sistema de atendimento pré-hospitalar móvel em cinco capitais brasileiras”. Cad. Saúde Pública.; 24(8):1877-86.

MS,2002. Ministério da Saúde (BR), “Portaria n. 2048, de 05 de Novembro de 2002. Regulamento Técnico dos Sistemas Estaduais de Urgência e Emergência”. Brasília-DF;

OEB, 2015a. OrthoInfo Editorial Board, homepage. 23 Jun 2015 <http://orthoinfo.aaos.org/topic.cfm?topic=A00522>

OEB, 2015b. OrthoInfo Editorial Board, homepage. 23 Jun 2015 <http://orthoinfo.aaos.org/topic.cfm?topic=A00680>

Pahl, G; Beitz, W; Feldhusen,J; and Grote,K.", 2005. *Projeto na Engenharia*. Edgard Blücher,1st edition

Pickering A., Mason S., Turner J., Bradley P. and Irving S., 2009. *Private Communication*. “Emergency Services Review: A Comparative Review of International Ambulance Service Best Practice”, NHS, UK.

Porcides, A. J., 2006. *Private Communication*. “Manual de Atendimento Pré-Hospitalar, C. de Bombeiros do Paraná”.

Rozenfeld, H., Forcellini, F., Amaral, D.C., Toledo, J.C., Silva, S.L. and Alliprandini, D.H, Scalice, R.K., 2006. *Gestão de desenvolvimento de produtos: uma referência para a melhoria do processo*, São Paulo, Saraiva, 1st Edition.

Silva, N. C., Tolstenko L. 2012. ”Avaliação de Indicadores Operacionais de um Serviço de Atendimento Móvel de Urgência”, *Journal of Cogitare Enfermagem*, Vol. 17(3), p. 471-7.

9. RESPONSIBILITY NOTICE

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