Portable Surgical Table

Engineering World Health Design Competition Submission

Problem Definition

The need for surgical tables in developing nations is the focus of our project. It is imperative to the success of surgeries that they be performed in a sterile environment, which is a condition which most existing surgical tables in developing nation hospitals do not provide. It is also very important that surgeons have easy access to the patient they are operating on, which is often limited by the non-adjustable height of these surgical tables. Many doctors in developing nation hospitals are performing surgery on wooden tables which cannot be sterilized and have no height adjustment. A number of surgical tables that are brought into these hospitals are able to be sterilized and adjusted, but they are large, heavy, and require either electricity or complex hydraulic mechanisms. Additionally, these tables frequently come with a high price tag. These factors make delivering surgical tables to hospitals in developing nations and maintaining them there extremely difficult.

Samaritan's Purse is a humanitarian aid organization that provides the movement of medical equipment from developed nations into under-resourced areas of the world. We partnered with this organization to design a lightweight, portable, durable, and low-cost surgical table for use in Samaritan's Purse partner mission hospitals who provide medical care for developing communities. We are developing a low-cost surgical table that will allow for the movement of equipment to be easier, and with a purely mechanical design there will be no electricity needed or complicated issues to solve.

Impact in Developing World

The surgical table we have designed will address these pressing problems with current surgical tables in developing nations. It will decrease the chances of infection in mission hospitals and developing nations. Having a viable work surface that can be easily maintained and cleaned will allow patients to see better recovery times and decrease the likelihood of contamination due to non-sterilized tables. Additionally, our table is foldable so that it can be easily transported from developed nations to hospitals across the globe. Our surgical table is also fully mechanical and height-adjustable. It will allow surgeons to operate comfortably with easy access to patients, and will be easy to maintain, coming with simple maintenance instructions and using parts and materials that are commercially available.

Currently, there is a surgical table that accomplishes many of the same goals as our design. However, doctors we surveyed found height adjustment difficult, and it is extremely expensive. In comparison with currently available products for similar use, our surgical table will cost considerably less, allowing many more units to be distributed. Additionally, our table will be easy and relatively inexpensive to maintain. This is important, as complicated maintenance and repair is not realistic in mission hospitals. By providing a surgical table that is easy to use and maintain, we will ensure that doctors in developing countries will continue to use the tables provided to them. The goal of this project is to allow organizations such as our partner, Samaritan's Purse, to bring surgical tables to global communities at a lower cost, enabling them to help more communities.

Required Performance Specifications

In order to determine the specifications for our design, we communicated with the biomedical engineering team at Samaritan's Purse. We also sent a context assessment to multiple surgeons who have performed surgeries in Samaritan's Purse hospitals. Based on the engineers' and surgeons' answers to our questions about specific needs of hospitals in the developing world, we created a list of specifications for our product. We also based a number of our specifications on aspects of a table that is currently used by many organizations in an international capacity. In our discussion with Samaritan's Purse, we evaluated what aspects of that table were ideal for its use and what aspects would need to be changed for our product.

Our primary concern was to create a table that is safe to be used for surgery. Based on this priority, our partners determined that the table must support the weight of a patient up to 400lbs. Additionally, the tabletop surface needs to be flat, sterilizable, and sturdy. To safely hold a patient, we planned to create a tabletop of dimensions of at least 28" x 82", the standard dimensions of the commonly-used NATO litter [1].

In order to support safe surgeries, it is also important that the surgeon is comfortable using the table. Thus, our table must be height-adjustable to allow for the performance of various surgeries by various surgeons. The surgeons we surveyed also said that they would prefer to use a flat surface to a NATO litter.

Beyond these basic requirements, we determined a few more specifications for the table in order for it to fulfill its purpose of being used in hospitals in developing nations. First, the table needs to be portable (i.e., lightweight and able to be folded compactly) so that it can be easily transported to developing nations. Second, the table must be simple to assemble and maintain. Finally, the table must be low-cost. We defined low-cost as less than $5000, the cost of similar products in the current market.

Implementation of Prototype

To construct our prototype, we used materials entirely from 80/20 Inc. [2]. We did this so that the design will be easy for humanitarian organizations to manufacture and so that replacement parts necessary for maintenance can be easily acquired.

We developed a prototype with a central tabletop and two additional folding tabletop surfaces. The tabletop total size is 23” x 82” and is supported by a frame of aluminum extruded bars. The table frame is supported by four height-adjustable legs. The entire table assembly sits on four self-leveling feet [See assembly in Appendix B]. For portability, the two fold-out tabletop surfaces and the four legs can be folded into a compact orientation [See folded assembly in Appendix C]. All extruded aluminum bars used are 25mm x 25mm thick. The following sections address the components of the table in greater detail.

Figure 1: Complete physical prototype

Central Tabletop

The central tabletop surface is made of a 6mm-thick high-density polyethylene (HDPE) material. Its dimensions are 41” x 23”. It is supported by a 41” x 23” frame made of five extruded aluminum bars [See central tabletop subassembly in Appendix D].

Folding Tabletop Surfaces

Each folding tabletop surface is made of the same 6mm-thick HDPE material. Each folding tabletop surface is 20” x 23” and is supported by a 20” x 23” frame made of four extruded aluminum bars. The

frame of each folding surface is attached to the frame of the central tabletop with two hinges [See folding tabletop subassembly in Appendix E].

Legs

Each leg is made of a 21” long extruded aluminum bar attached to another 24” long extruded aluminum bar with two friction-locking linear bearings. These bearings are loosened and tightened with a handle, allowing for the legs to smoothly glide past one another and be locked in place for height adjustment. Each leg is attached to the central tabletop frame with a pivot subassembly. Each pivot is bracketed to a short extruded aluminum bar that is bolted to the tabletop frame. This bar lays flush against the tabletop frame when the legs are in standing position, keeping the legs secured at a 90-degree angle with the table [See leg subassembly in Appendix F].

Supports

Two 23” and one 21” extruded aluminum support beams run between the legs parallel to each shorter end of the table. Two 39” extruded aluminum support beams run between the legs parallel to each longer side of the table. Two 18” 45-degree support extruded aluminum bars support the frame of the folding tabletop pieces.

Initial Assembly

We have created a detailed parts list [See Appendix G] and assembly manual. These documents can be shared with humanitarian aid organizations who will use this table. They then will be able to order the exact parts needed for the table and assemble them easily on-location.

Set Up

It is likely that many aid organizations will assemble the table in their base location, fold the table into its compact orientation, and ship it to hospitals in developing nations around the globe. For this reason, the assembly manual we created includes simple set-up and tear-down instructions. These instructions will allow non-technical workers in hospitals to quickly and easily set the table up for use.

The table setup consists of pivoting the legs to be perpendicular to the table frame and unfolding the smaller tabletop sections. Then, the 8 support beams are added for stability. Fully setting up the table takes about 13 minutes with one person, and teardown takes only 4 minutes.

Proof of Performance

Stability

Table stability was the most important aspect of testing. Static and dynamic loading were tested according to international standards [3-4]. Static testing showed slight bowing (2”) in the HDPE tabletop with a load of 300lbs, but no permanent deformation in any part of the table (figure 2). Dynamic testing resulted in some movement, but clinical testing may be required to determine whether this compromised the stability of the table.

Figure 2: Testing the table with an ISO-standard dummy according to IEC standards.

Flat, Sterilizable, & Sturdy Tabletop

The tabletop is a flat surface made of high-density polyethylene (HDPE). This material lacks deep ridges and is non-reactive with disinfecting chemicals, making it ideal for sterilization. We ensured that the tabletop would provide sufficient support for patients by supporting the central section of the tabletop with aluminum extruded bars on all four sides, as well as a crossbar under the center of the tabletop. The folding portions of the tabletop are supported by aluminum bars on all sides, as well as by triangular supports attaching two sides of each folding surface to the table legs.

Height-adjustable

The height of the table can be adjusted with sliding friction-lock mechanisms on each leg of the table. The height of the table ranges from 29” to 38”. Standard heights can be marked on each leg to allow for a level table surface.

Portability

When the table is in the folded position, the disassembled support beams can be neatly laid inside the frame of the table and the whole table can be secured with straps. When folded, the dimensions of the table are 41”x23”x8”. This size will allow the table to fit in shipping cases and delivered internationally. The table weighs 60.5lb and thus can be lifted by one person.

Simple Assembly, Deployment, and Maintenance

The table is assembled entirely with parts from one company, 80/20 Inc. This allows for cheap and simple ordering of parts for assembly and maintenance. Additionally, hardware used to assemble the table is standard, and can be easily acquired in many countries. 80/20 Inc. also provides the service of manufacturing parts, which decreases the assembly time for the user. Table deployment is estimated to take around 13 minutes , but clinical testing may be needed to determine the average deployment time. Follow-up assembly of the table once it has been delivered, along with table deployment and folding is outlined in the assembly instructions.

Low Cost

The cost of building our first and final prototypes combined cost our team a total of $2,218.09. Based on cost estimates from the manufacturer, we estimate that the prototype could be replicated for a total of $1533.14, including manufacturing and shipping costs. This estimate does not include tax, as the manufacturer supports non-profit organizations by allowing them to purchase parts without tax. This is far lower than the price of Used surgical tables that cost around $5,000. Our design allows for increased resource allocation for other medical equipment to be sent or be spent in other areas.

Business Plan

Market

This technology will be marketed to organizations who are looking to provide aid in third-world countries or communities facing war or other disasters. This technology is not intended to be sold to such organizations for profit. Rather, it is intended to be distributed to organizations desiring to use it, allowing them to better help global communities at a minimal cost.

Funding

The development of this technology was funded by Samaritan's Purse. Further manufacturing of the product will be funded by individual organizations desiring to utilize our design.

Manufacturing

Our development of this technology includes the creation of a manufacturing guide. This guide includes all the necessary parts for the table, complete machining instructions, and assembly instructions. Organizations wishing to use this table will be able to obtain the manufacturing guide and then decide the manufacturing option that works best for them. Organizations can simply purchase and manufacture all necessary parts internally, they can purchase the parts and have the machining done prior to the delivery of the parts, or they can even have the table completely machined and assembled prior to shipment. Since all of the parts are available through 80/20 Inc., the organizations would only have to coordinate with 80/20 Inc. for all of their purchasing, machining, and assembly needs. For cost of parts and machining see Appendix G.

Distribution

The distribution of this technology is largely dependent on the distribution strategies of individual organizations. We will coordinate with Samaritan's Purse to distribute the manufacturing guide to desiring organizations. It will then be up those organizations to decide how to distribute the physical tables. Samaritan's Purse, for example, will likely assemble the tables and distribute them in compact form in coordination with 80/20 Inc., then send the products out from their headquarters in the U.S. to mission hospitals worldwide.

Regulations

To be used within the United States, this technology would need to be certified by the FDA. However, given that its purpose is to be used in mission hospitals, the table can be implemented abroad prior to FDA approval. The testing we have done on the table is fit with standards put out by the International

Electrotechnical Commission and the International Organization for Standardization. Further clinical testing will likely bring about more design improvements to increase the performance of the table.

Market Research

Surgical tables vary based on the type of surgery performed, but for our literature review we have chosen to compare tables that are designed for general surgeries. The most important qualities of a surgical table are allowing a surgeon access to the surgical site, being sturdy enough to support a variety of patients, and durable enough to perform surgeries for a long time [5]. Surgical tables used in the United States follow the same general form: a heavy column supporting a strong tabletop which can hold a firm, thin mattress. Many surgical tables are made to be bolted into the floor to prevent the table from moving during surgery [6]. The price range of surgical tables varies, but they start at a high price. According to an article from medical equipment provision experts, "the price range of a general surgery table can go from the extreme of your basic manual table for $20,000 to a high-end table at $70,000 for complex surgical procedures" [7].

For our project, we wanted to research not only surgical tables used in hospitals, but also current designs of portable surgical tables (PST). Some litter carriers are marketed as PSTs, but these do not serve the same purpose and are not designed to be as sturdy as a PST. There are a few types of litter carriers on the market, and only two PSTs were found in our review. The most notable litter carrier was made by Faretec, called the EL3000 NATO Wheeled Litter Carrier [8]. The litter carrier is lightweight, foldable, mobile, and can hold up to 500lbs. using a standard NATO (North Atlantic Treaty Organization) litter. However, it is not designed for surgeries but only for safe transportation of a trauma patient. Another comparable litter carrier is one made by North American Rescue, and serves similar purposes as the Faretec carrier, though it is sold at a lower price [9]. One comparable PST is made by Ferno Military Systems, designed for in-flight surgeries [10]. However, this table weighs over 300lbs. and is not available for civilian purchase.

Patent Research

In addition to market research, we completed a patent search to further research comparable designs. The most relevant category of patent applications was found to be A61G 13/105, "Portable, foldable, or collapsible tables, e.g. for surgery or treatment" [11]. Related applications in this category included litter carriers (such as the NATO carrier cited above) and modified massage tables. All of these tables are

designed to support a person while being easily folded and transported. However, none of the tables found included both the mechanism of folding and height-adjustable legs.

Appendices

Appendix A – Prototype Assembly: Deployed

Figure A.1 - Physical Prototype

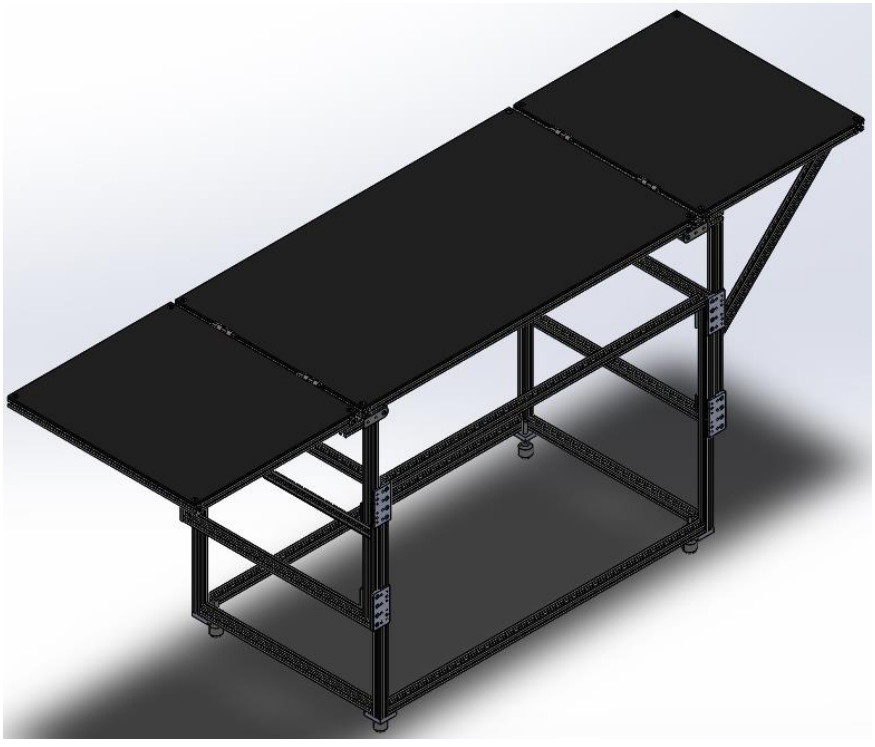

Figure A.2 - Digital model of prototype

Appendix B – Prototype Assembly: Folded

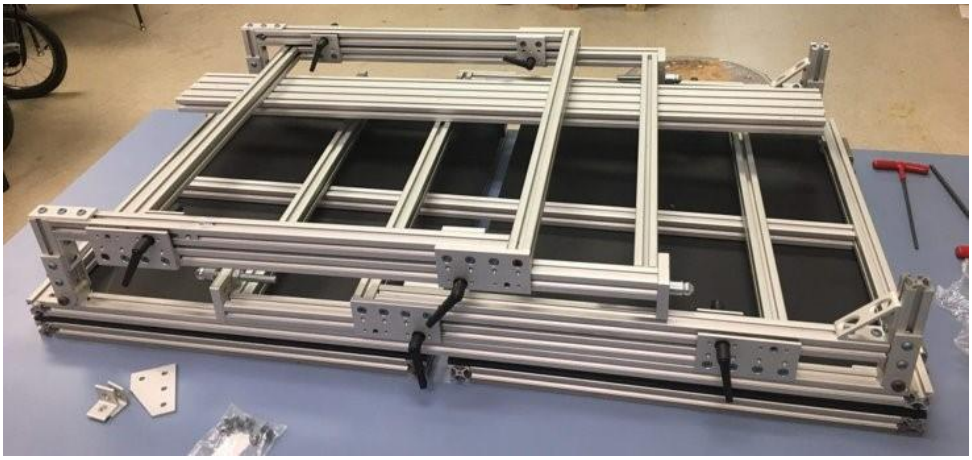

Figure B.1 - Prototype in folded position

Appendix C – Tabletop Subassemblies

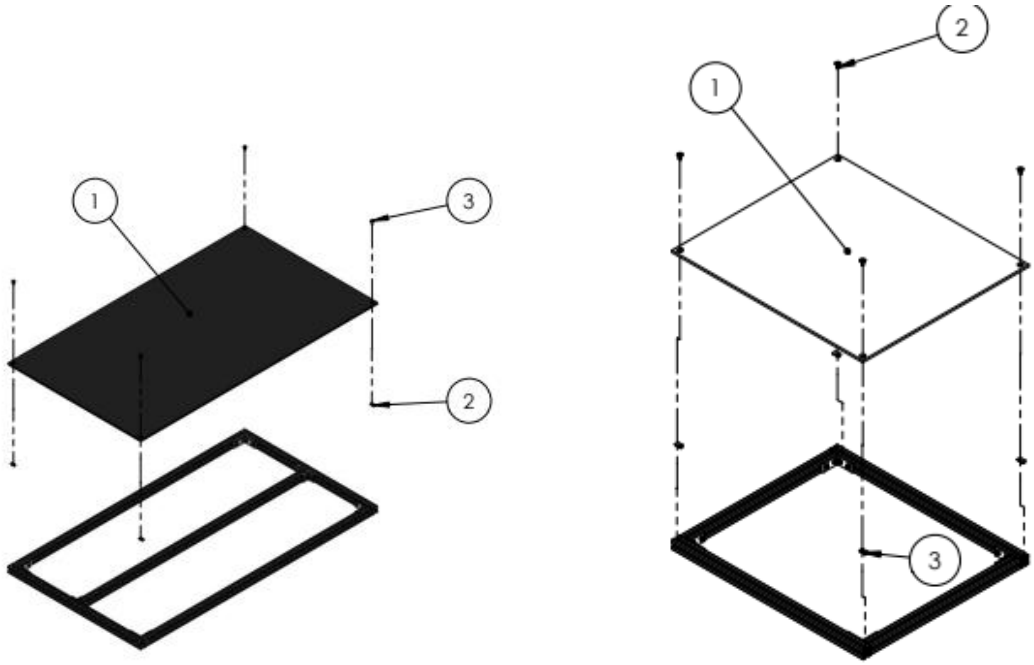

Figure C.1 - (Left) Central tabletop subassembly. (Right) Folding tabletop subassembly.

Appendix D – Leg Subassemblies

Figure D.1 - Physical model displaying a single leg assembly

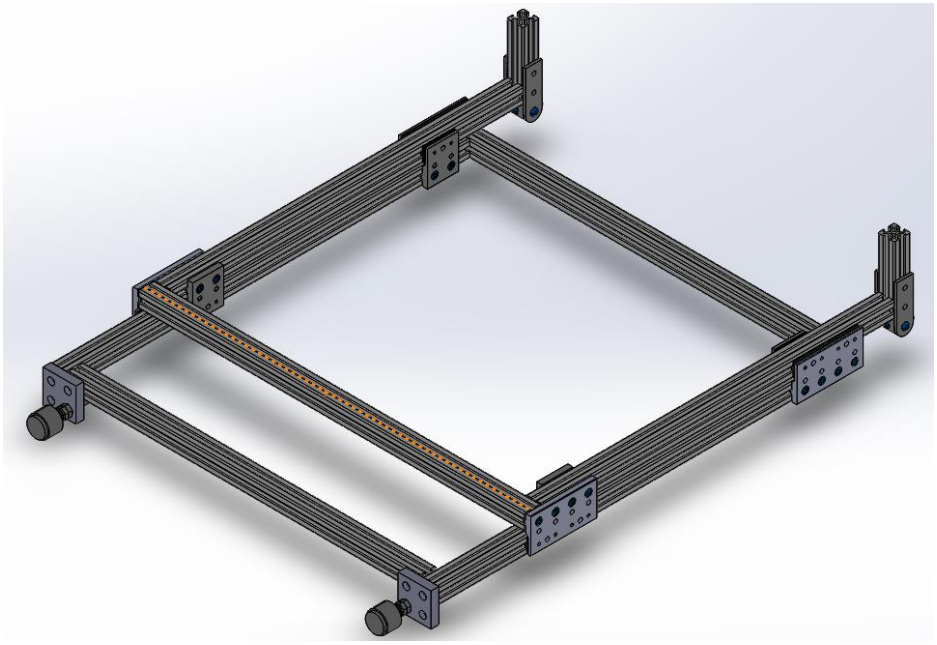

Figure D.2 - Digital model of leg subassembly

Appendix G – Parts List

Part Name	Description	Amount Used	Cost After Machining
25-2525	25mm X 25mm T-SLOTTED EXTRUSION 6M BAR	797	$235.62
65-2651	6mm BLACK HDPE - Stock 48"x96"	1	$81.99
25-2142	50mm X 50mm BASE PLATE W/ M10 CORNER TAP	4	$54.60
25-2796	25 S L-HANDLE LINEAR BEARING BRAKE	16	$204.80
25-6730	25 S SHORT SINGLE UNIBEARING ASSEMBLY	4	$136.60
25-4180	25 S 0 DEGREE LIVING HINGE W/ STRAIGHT P	4	$72.60
25-6732	25 S LONG SINGLE UNIBEARING ASSEMBLY	4	$180.20
25-4115	25 S 4 HOLE INSIDE CORNER BRACKET	16	$61.60
65-6108	M5 BALL END 'T' HANDLE HEX WRENCH	1	$6.40
65-6107	M4 BALL END 'T' HANDLE HEX WRENCH	1	$5.00
12096	STAINLESS STEEL HINGE, 60X60, NONDETACHABLE	4	$84.60
25-2575	25-2525 X 480mm 45 DEGREE SUPPORT	4	$67.20
25-2015-plain	25-2525 PLAIN END CAP BLACK W/PUSH-INS	14	$14.56
25-4118	25 S 3 HOLE JOINING STRIP	4	$16.36
25-4136	25 S 4 HOLE INSIDE GUSSET CORNER BRACKET	12	$67.80
65-2207	M10 ECONOMY ANTI-VIBRATION MOUNT	4	$95.00
11 6514	M6 X 14mm SHCS [BLACK]	4	$1.08
13-6510	M6 X 10mm BHSCS [BLUE]	6	$1.14
13-6512	M6 X 12mm FHSCS [BLUE] - HDPE	28	$5.60
40-3914	10S M6 ROLL IN T-NUT W/BALL AND SPRING	8	$12.80
75-3404	M6 X 10MM BHSCS W/ ECONOMY T-NUT R	18	$8.10
11 6518	M6 X 18mm SHCS [BLACK]	10	$3.70
75-3509	25 S M6 X 1.0 DOUBLE ECONOMY T-NUT BRIGH	56	$50.96
		Total:	$1,468.31
		Total w/ Shipping:	$1,545.07
		Total w/ Tax:	$1,724.48

Appendix I – References

[1] NATO NSN# 6530-01-663-2308, "Wheeled Litter Carrier." North American Rescue. Online: https://www.narescue.com/wheeled-litter-carrier.html [Accessed 27-Oct-2019]

[2] 80/20 Inc. The Industrial Erector Set. https://8020.net/

[3] 2016. Medical electrical equipment –Part 2-46: Particular requirements for the basic safety and essential performance of operating tables. IEC 60601-2-46 Figure and Table AA.1. International Electrotechnical Commission. Available: https://global.ihs.com/

[4] 2012. Wheelchairs — Part 11: Test dummies. ISO 7176-11:2012. International Organization for Standardization. Available: https://global.ihs.com/.

[5] "How Much Does a General Surgery Table Cost?". Meditek. 18-Jul-2016. [Online]. Available: https://www.meditek.ca/cost-of-general-surgery-table-options-accessories-prices/. [Accessed 27-Oct-2019]

[6] "Healthcare Equipment | Disinfection & Sterilization Guidelines | Guidelines Library | Infection Control | CDC," 24-May-2019. [Online]. Available: https://www.cdc.gov/infectioncontrol/guidelines/disinfection/healthcare-equipment.html. [Accessed: 27-Oct-2019].

[7] "April 2007 -Operating Rooms - Tables." [Online]. Available: https://cdn.hpnonline.com/inside/2007-04/0704-OR-Tables.html. [Accessed: 27-Oct-2019].

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[11] A61G 13/105: "Portable, foldable or collapsible tables, e.g. for surgery or treatment." PatFT (Patents Full-Text and Image) database. https://patft.uspto.gov. [Accessed Apr-2020]