A Look Into the Pitfalls and Future of U.S. Medical Device Regulation

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By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Signed: _____

Approved: _____ Date _____
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Introduction

Cardiovascular disease (CVD) is the leading cause of death amongst both men and women, accounting for roughly one in every four deaths in the United States according to the CDC (Greenland, 1999; Fryar, 2012). Additionally, as of 2015, 41.5 percent of Americans had at least one CVD condition, with a projected increase to 45 percent by 2035 (Khavjou et al., 2016). Middle-aged people (35-55) are more at risk for CVD than young adults. Recently, however, the age group most at risk has been decreasing from the ages of 60 and above to the ages of 35 and older. Cardiovascular disease costs the US $318 billion per year in medical fees with an additional $237 billion coming from indirect costs which include loss of productivity due to both morbidity and premature mortality (Khavjou et al., 2016). Cardiovascular disease risk factors can be classified as non-modifiable and modifiable, the former of which cannot be changed. These non-modifiable risk factors include, but are not limited to age, ethnicity, and genetics.

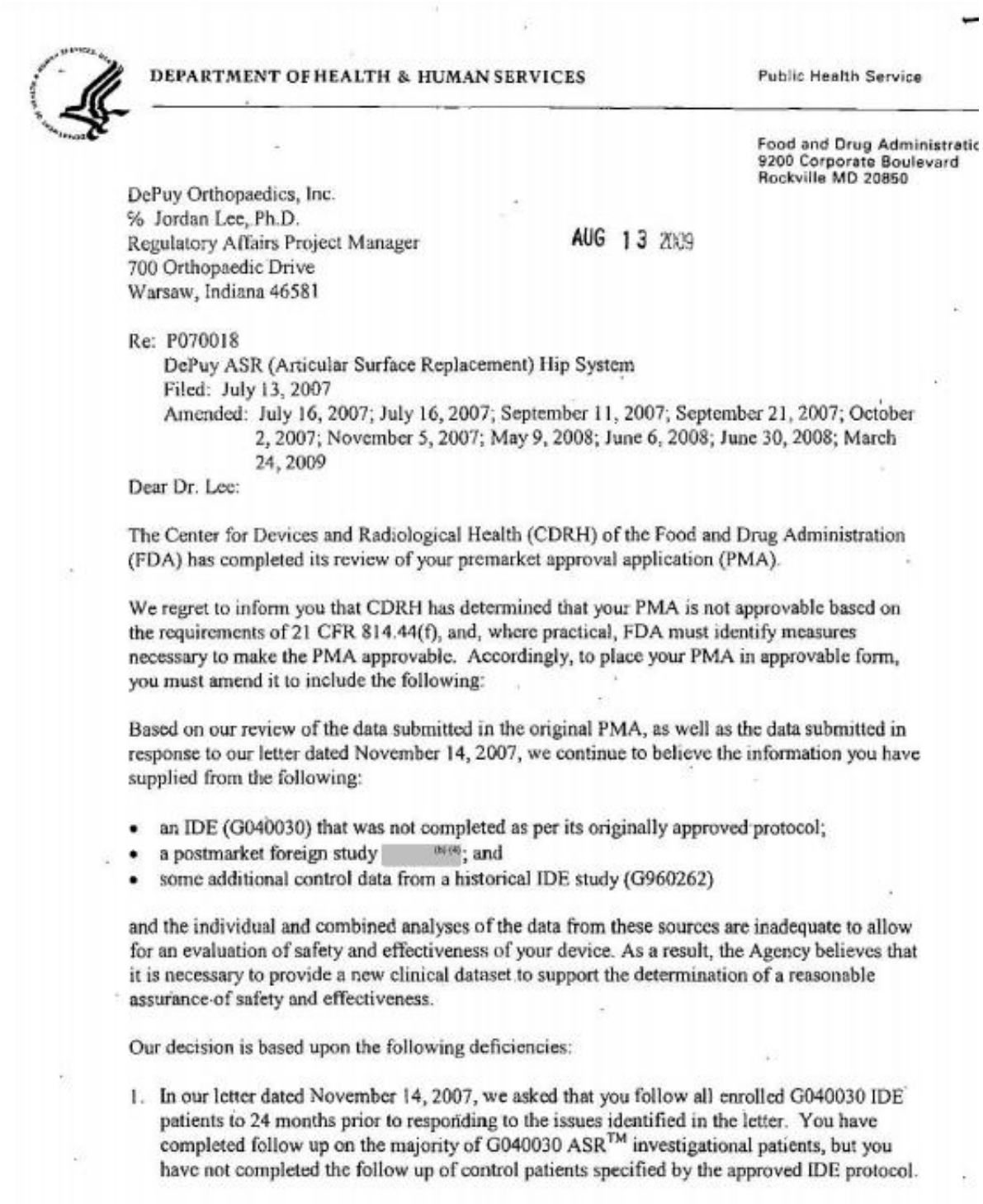
With a change in behavior, modifiable risk factors can be controlled or eliminated. The three key risk factors, smoking, high blood pressure, and high cholesterol are shared by 47% of Americans (Smith et al., 2004). Through daily physical exercise and by changing one's diet to exclude trans fats, saturated fats, and salts, one can reduce the risk of developing cardiovascular disease. Reduction of alcohol intake to no more than one and two drinks a day for females and males, respectively, has been shown to decrease high blood pressure (Fryar, 2012). The success of these lifestyle changes is assessed by physicians and other healthcare specialists who use a variety of devices in clinic.

Because cardiovascular disease affects a large number of people, it is imperative that biomedical engineers make an effort to mitigate it. Engineers have created many devices that indicate different aspects of cardiovascular health. These devices, including electrocardiograms,

blood pressure cuffs, and pulse oximeters, are commonly found in clinics and help healthcare professionals assess a patient's level of risk for cardiovascular disease. The distribution of such devices to the healthcare market in the United States is regulated by the Food and Drug Administration (FDA). The current FDA regulations for medical device approval are harmful to patients, inventors, and healthcare professionals. Specifically, the 510(k) process has allowed some devices to cause damage to patients, and post-market surveillance policies didn't allow for FDA to aggregate and release reports detailing failures or provide guidelines for use. Analyzing global regulatory policies will provide insight into what policy changes would create equal approval opportunities for medical devices in addition to improving public health.

Case Context

How does the regulation and approval of medical devices impact healthcare professionals, inventors, and patients, and how might it be improved? All treatment and diagnostic equipment defined as a medical device in the United States are subject to approval by the Food and Drug Administration (FDA). The approval process, while codified, is not stratified in its application to new medical devices. In an essay on innovation in medical technology, Ariel Stern argued that the FDA approval process averaged quicker approval times for new medical devices than for pioneer (the first within its product code) medical devices. Stern supported this claim by comparing the average pre-market approval time for "high-risk"-classified devices (18.1 months) against that of a device that is the first of its kind (22.5 months). In the same paper, the author used an empirical model of approval time based on Carpenter's 2010 model to illustrate the longer approval times for new devices (Stern, 2016).



DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Food and Drug Administratic
9200 Corporate Boulevard
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DePuy Orthopaedics, Inc.
% Jordan Lee, Ph.D.
Regulatory Affairs Project Manager
700 Orthopaedic Drive
Warsaw, Indiana 46581

AUG 13 2009

Re: P070018
DePuy ASR (Articular Surface Replacement) Hip System
Filed: July 13, 2007
Amended: July 16, 2007; July 16, 2007; September 11, 2007; September 21, 2007; October 2, 2007; November 5, 2007; May 9, 2008; June 6, 2008; June 30, 2008; March 24, 2009

Dear Dr. Lee:

The Center for Devices and Radiological Health (CDRH) of the Food and Drug Administration (FDA) has completed its review of your premarket approval application (PMA).

We regret to inform you that CDRH has determined that your PMA is not approvable based on the requirements of 21 CFR 814.44(f), and, where practical, FDA must identify measures necessary to make the PMA approvable. Accordingly, to place your PMA in approvable form, you must amend it to include the following:

Based on our review of the data submitted in the original PMA, as well as the data submitted in response to our letter dated November 14, 2007, we continue to believe the information you have supplied from the following:

- an IDE (G040030) that was not completed as per its originally approved protocol;
- a postmarket foreign study [redacted]; and
- some additional control data from a historical IDE study (G960262)

and the individual and combined analyses of the data from these sources are inadequate to allow for an evaluation of safety and effectiveness of your device. As a result, the Agency believes that it is necessary to provide a new clinical dataset to support the determination of a reasonable assurance of safety and effectiveness.

Our decision is based upon the following deficiencies:

1. In our letter dated November 14, 2007, we asked that you follow all enrolled G040030 IDE patients to 24 months prior to responding to the issues identified in the letter. You have completed follow up on the majority of G040030 ASR™ investigational patients, but you have not completed the follow up of control patients specified by the approved IDE protocol.

Figure 1. FDA Letter to DePuy Orthopaedics requesting safety data for the ASR hip replacement. (Meier, 2012).

The FDA approval process, most notably the 510(k) process, suffers from its inability to assess the safety of an approved device after it enters the market. Curfman and Redberg describe the DePuy (subsidiary of Johnson & Johnson) ASR XL Acetabular System hip implant, a modification of the earlier ASR Hip Resurfacing System. Because the ASR XL was a "substantially equivalent" device to an existing and approved device, it did not have to undergo clinical trials. The class III (high-risk) device was later recalled due to its reported 1 in 8 failure rate caused by erosion of metal particles which were free to enter the bloodstream, causing many patient deaths. By law, class III devices must undergo clinical trials, following the stricter premarket-approval (PMA) pathway. These devices should not be approved by the 510(k) process alone without supporting clinical data, but often times high risk devices will slip through the cracks and skip trials. The ASR is such a device, as its PMA was initially rejected by the FDA, who in a confidential letter asked for additional safety data which DePuy did not provide, see Figure 1 (Meier, 2012).

The 510(k) process is usually sought out by companies as a quicker and less expensive option to get a product to market. Jason Howard adds that the 510(k) incentivizes companies to seek approval via this pathway by its large difference in pricing compared to the PMA – thousands versus hundreds of thousands of dollars. The author notes that the former process requires much less paperwork as well, citing the ASR XL's three-page 501(k) application's length and the 44-page PMA application submitted by Smith & Nephew for their Birmingham hip resurfacing system (Howard, 2016).

The Institute of Medicine (IoM) in 2011 released a report on the 510(k) process and demonstrated its inability to ensure safety and recommended that the clearance type be eliminated. The IoM also recommended that approved devices be monitored throughout their

market life cycle. This proposal was met with criticism and was not adopted by the FDA (Curfman & Redberg, 2012). In the recent past, others have made suggestions for the improvement of the approval process. Dhruva and Redberg argue in favor of post-market surveillance, citing the Sprint Fidelis defibrillator lead which was recalled after reports of patient deaths caused by the device in 2007. Because few studies existed which analyze the medical device approval process, the authors designed a study of their own. They found that 78% of approved devices were not considered high-risk. It was argued that this figure is alarming due to the number of devices that end up having to be recalled, further illustrating the need for a better post-market surveillance system. The authors declare that increased political funding and support is necessary for both the FDA and European Union in order to implement better programs. If funding is not made available for improved device assessment, the authors say, then data should be made available to the public (Dhruva & Redberg, 2012). Similarly, Feldman et al. wrote that inability to surveil products post-approval leaves the responsibility of failure reporting to academics, manufacturers, and end-users.

Additionally, the FDA is unable to regulate clinical procedure and healthcare professional use of approved devices, leading to potential off-label use which may harm patients. Professional societies, such as the American Heart Association, are often left to oversee the use of medical technologies in their domain, as well as provide best practices of their use. While they are not immune to bias and conflict of interests, the authors contend that they are useful vehicles of discussion and drive quality improvement (Feldman et al., 2007). This research will determine the best implementation of a new policy which optimizes patient health while allowing the greatest number of new devices in a timely manner comparable to that of previous devices.

Societal Interactions with Medical Devices

Each of the key stakeholders described in the research question are heavily impacted by the regulation of medical devices. The societal context of medical devices and medical technologies can be described using the actor network theory (ANT) and technology-in-practice (TIP) frameworks. Prout (1996) proposes ANT as a means to discuss technology in terms of its contributions to peoples' health. The approach is used to describe the role of the metered dose inhaler in the network. The technical portion of its role is its delegation of work as a stand-in for someone who must give a specific dosage of medicine. The authors describe the program of action (correct drug administration) as well as the user antiprogram (incorrect use of the device) of the device. The inhaler's network was considered to be the interaction between the engineers attempting to bring user action in line with the program (Prout, 1996).

Yeung and Dixon-Woods in a review article provide an analysis of the medical device regulatory landscape using the insights from the field of regulatory studies. The focus of the paper is action-forcing design, which seeks to exclude non-compliance by both encoding and enforcing a rule. Patient safety is able to be encoded within the design of a technology itself. The authors explore criticisms of regulatory design, including the argument that regulatory design undermines the expertise of professionals as well as their morality. The idea that technology has the ability to enforce morals is brought about and supported by the work of others in the STS field, including Latour and Jelsma. The authors argue that regulatory design should be seen as more than a risk-management tool, and that care should be taken to identify the values that a technology encodes as well as the social ordering it brings about. Regulatory design is stated to influence the professional environment and possess the ability to be a fail-safe for clinical judgement for the ultimate goal of ensuring patient safety (Yeung & Dixon-Woods, 2010).

Actor-network theory can be used to explore power dynamics in the healthcare system. Policy changes have a large downstream effect on influence. At the micro-level, nurses have more influence due to concerns about healthcare service inefficiencies, while at the macro level, budget cuts have led to an increase in local hospitals' input in government. By examining the healthcare environment using ANT, the success of a technology may be assessed by how it interconnects different actors and functions in existing networks (Cresswell, Worth, & Sheikh, 2010).

Timmermans and Berg (2003) describe TIP as a mixture of social essentialism and technological determinism, in which technology is neither a deterministic super-actor that dehumanizes users nor is it a blank slate, but a combination of professionals, devices, patients, and records. The use of this framework allows for one to examine the health-benefiting goals that medical technologies allow people to accomplish by delegation of work (Timmermans & Berg, 2003). Using TIP, Gibson et al. were able to consider the cultural significance associated with a given technology that varies across different members of the network. The authors relate their interviews with men who use mechanical ventilators to aid their muscular dystrophy. From the interviews, the authors explore self-understanding of the body in conjunction with technology and ask questions such as, where does the body end and the device begin? (Gibson et al., 2007). Examining the sociotechnical dimensions of the technology using these frameworks will inform the creation of new policy.

Research Question and Methods

The United States of America's Food and Drug Administration is the agency responsible for protecting the public health of citizens and ensuring the safety and effectiveness of drugs and

medical devices. The FDA states that their purpose is "protecting consumers and enhancing public health by maximizing compliance of FDA regulated products and minimizing risk associated with those products." (Food and Drug Administration, 2017). Their current policies in place to regulate medical devices do not allow them to best achieve this goal. New medical devices enter the market at a rate slower than proposed by the FDA, and high-risk devices, like the ASR XL have been demonstrated to bypass the need for clinical trials (Meier, 2012). While the FDA has implemented protocol to monitor devices that have hit the market, it is not as effective as it could potentially be.

The goal of this research was to answer the question, how do changes in policy can create equal opportunities for medical devices to be marketed as well as improving public health? In order to answer the question, I began with a review of current medical device regulation policies from three nations around the globe, being Japan, South Africa, and China. For each country, I researched their risk classifications of medical devices, costs for the manufacturer of a device, and their method of post-market surveillance and monitoring, if applicable. To conduct my policy analysis, I drew from Bardach's guide to policy analysis as well as the Center for Disease Control's policy analysis framework. The criteria used to determine which policy would best improve upon the parameters outlined above were 1) impact on public health by measure of how strict an application is, 2) impact on public health by measure of involvement of stakeholders in evaluating safety, and 3) impact on opportunity by cost to the creators of the device. Operational issues regarding implementation were considered in limited scope, as well as some outcomes of such a policy being enacted.

Results

The analysis of different policies across four nations shows that the best alternative suited to improve public health and provide equal opportunities for new medical devices is in Canada. Canada's medical device regulation policy provides for strict classification of devices, requiring a large dossier including clinical data for the highest-risk devices. Their policy also implements a form of post-market surveillance that places responsibility on healthcare facilities such as hospitals and clinics to report device safety incidents, which the regulating agency aggregates, disseminates, and takes action upon. Finally, the overall cost of submitting a device for approval is less expensive to manufacturers than it is under current FDA policy.

United States – Food and Drug Administration (FDA)

In order to differentiate between devices, the FDA uses a risk-based classification system, specifying three classes, Class I, Class II, and Class III devices. Class I devices are low-risk to patients, and most of these devices require pre-market notification. These include devices such as toothbrushes and stethoscopes. Class II devices are of medium risk, and most require a 510(k) pre-market notification (PMN). The 510(k) application in addition to technical specifications of the device and labels to be included with packaging, requires the proof of substantial equivalence (SE). In order for a device to be SE to a predicate, it must: 1) have the same indications for use, 2) have similar technological characteristics, and 3) raise no safety and effectiveness concerns where it differs with the predicate device. After 90 days, the FDA returns one of two determinations of the device, SE or Not SE. An NSE may be accompanied by a request for additional information, after which the applicant may resubmit their PMN within a new 90-day window. Additionally, if the applicant receives an NSE, they may submit a *de novo* application

within 30 days. De novo applications allow for the classification of devices which have no predicate into low-moderate risk and may also be submitted without first submitting a 510(k) PMN. While 90 days is the best-case scenario for approval, the FDA is known to ask for additional information multiple times before approving some devices, causing the average approval time to be about six months from the initial submission (Emergo, 2017). The costs for submitting a 510(k) PMN and a *de novo* application are $11,594 and $102,299, respectively. Small businesses (annual sales totaling <$100M) pay a reduced fee of 25% of the base price (Food & Drug Administration, 2019b).

Class III devices are of high-risk to patients and require approval of a pre-market approval (PMA) application. A PMA includes a clinical study report, technical data, non-clinical laboratory studies, labeling, and compliance to quality system regulations (Food & Drug Administration, 2019b). Devices which can be proved SE to a device marketed before the 1976 Medical Device Amendments may be able to be classified using the 510(k) PMN pathway. The cost of a PMA is $340,995.

Section 522 of the Public Health Services Act allows the FDA to conduct post-market surveillance of Class II and Class III devices which may have adverse health consequences in the event of a failure. This applies to devices to be implanted for more than one year as well as those which sustain or support life. For up to 36 months, the FDA may require prospective surveillance of the device, unless a longer period is deemed necessary (Food & Drug Administration, 2016). In the case where the FDA and the manufacturer disagree that a longer period is required, the dispute is to be settled by the Medical Devices Dispute Resolution Panel (Food & Drug Administration, 2019a).

Japan - Ministry of Health, Labor, and Welfare (MHLW)

Japan's MHLW is the regulatory body overseeing food and drug quality in Japan. The Pharmaceutical and Medical Devices Agency (PMDA) operating under the Pharmaceutical and Medical Devices Act of 2014 acts as the "technical arm" of the MHLW. The PMDA uses risk-based classification of medical devices, identifying four overall classes. Class I devices, known as General Medical Devices, are low-risk and include x-ray film, scalpels, and tweezers (Japan MDC, 2014; Pharmaceutical and Medical Devices Agency, 2014). These devices are self-declared and require only a submission of notification. The applicant is required to have a 3rd degree market authorization holder (MAH) license.

Class II devices are split into two categories, Designated Controlled Medical Devices, and Controlled Medical Devices. Designated Controlled Medical Devices require third-party certification by a registered certification body (RCB). An RCB uses Certification Standards provided by the MHLW, which comprises of adherence to the Essential Principles outlined by the International Medical Devices Regulators Forum (Lin, 2018). The application to the RCB must include appearance, dimensions, materials, and a summary of technical documents. Controlled Medical Devices are those which do not meet the Certification Standards by review of the RCB. Approval is instead required by the PMDA in a similar fashion to Class III and Class IV devices. For both Class II devices, the applicant must hold a 2nd degree MAH license, have a medical device manufacturer's license, and must comply with Quality Management System (QMS) requirements (compliant with ISO 13485).

Class III and Class IV devices are Specially Controlled Devices and are high -very high risk. Class III devices may be reviewed by an RCB or be approved by the MHLW and reviewed by the PMDA. Class IV devices may only be approved by the MHLW and approved by the

PMDA. The application requirements for Class III and IV devices are the same as those of Class II devices. Post-market surveillance is the duty of the manufacturer, who must ensure that their device complies with standards outlined by the MHLW.

South Africa - South African Healthcare Products Regulatory Authority (SAHPRA)

South Africa's Medicines Control Council was replaced by SAHPRA under the Medicines and Related Substances Amendment Act 14 of 2015 (Saidi & Douglas, 2018). The state of medical device regulation in South Africa is therefore in a transitionary period. A call-up action plan to regulate medical devices was published in 2018. The plan includes provisions for risk-based classification of devices, identifying four classes.

Class A devices are of low risk and require only market notification. Class B devices are moderate risk and require submission of a technical dossier to SAHPRA. Class C devices are moderate-high risk and require submission of evidence of pre-market approval from one of: the Australian Therapeutic Goods Administration, Brazil's National Health Surveillance Agency (ANVISA), Health Canada, the European Competent Authority, the Japanese Pharmaceuticals and Medical Devices Agency, or the US Food and Drug Administration. Class D devices are high-risk and require pre-market approval from two of the aforementioned agencies (SAHPRA, 2018).

All devices of Class B, C, and D which require registration are to be published each month in the Government Gazette of South Africa. Six months from publication, an application should be submitted and reviewed by SAHPRA internal staff. Because SAHPRA is new, no time frame for device approval nor a structure for fees are yet established (Keyter et al., 2018). In order to establish these regulations, SAHPRA would benefit from communicating with key

stakeholders, including manufacturers, hospitals, and other medical device regulating authorities should be looked to as an example.

Canada – Health Canada (HC)

Health Canada's Therapeutic Products Directorate (TPD) is the branch responsible for the regulation of pharmaceutical drugs and medical devices in Canada. TPD uses a risk-based classification system identifying four classes of device. Class I devices require only notification and the name of the device and its manufacturer. Class II device applications require inclusion of use purposes, a QMS (compliant with ISO 13485), and attestation by a senior official that the device satisfies safety requirements set by TPD. Class II applications cost $450. Class III devices additionally require a list of countries other than Canada where they are sold, a bibliography of reports regarding use, and supporting safety studies. Class III applications cost $7477. Class IV devices additionally require risk assessment, studies including preclinical and clinical data, process validation, software validation if applicable, and biological safety reports if manufactured from animal/human tissue (Canada, 2015). Class IV applications cost $24345. The timeframe for class I item approval is 120 calendar days. Class II, III, and IV devices are approved over 15, 75, and 90 days, respectively.

Health Canada collects post-market information from different sources and publishes Summary Safety Reviews (SSR) to inform citizens of safety investigations that may affect products they use. Because manufacturers must report safety incidents, Health Canada suspects under-reporting. Under Vanessa's Law, hospitals are required to report incidents (Canada, 2019). Health Canada plans to expand the Canadian Medical Devices Sentinel Network from which they seek reporting and includes more than 17 healthcare organizations and more than 260+

hospitals and facilities. Alongside this, Health Canada is developing an education program to aid hospitals in identifying medical device incidents. Table 1 provides a condensed view of each nation's policies.

Each agency uses a risk-based classification, though they differ in their specificity of risk. In each policy, higher-risk devices are subject to approval by the agency themselves and require the submission of more data. The cost to register a device differs widely, and all costs could not be found or were not available. Post-market surveillance policies tend to place responsibility on the manufacturers of the device, though the FDA and Health Canada extend this to allow for the agency to take some sort of action.

Name of Agency	**Risk Classification and Approval**	**Costs for Submission**	**Post-Market Surveillance**
Food and Drug Administration	I - Low Risk. II – Med Risk. 510(k) PMN or *de novo*. III – High Risk – PMA.	510(k) - $11594 De novo - $102,299 PMA – $340,995	Up to 36 months surveillance period for Class II, III devices
Japanese Pharmaceutical and Medical Devices Agency	I – Low risk. Notification only. II – Low-Med risk. RCB certification. III – High risk. RCB certification or MHLW approval IV – Very high risk. MHLW approval		Responsibility of the manufacturer.
South African Healthcare Products Regulatory Authority	A – Low risk. Notification only. B – Moderate risk. Submission of technical dossier. C – Moderate-high risk. Approval by foreign body. D – High risk. Approval by two foreign bodies.		
Canadian Therapeutic Products Directorate	I – Low risk. II – Med risk. Approval by TPD. III – Med-high risk. Approval by TPD with additional literature IV – High risk. Approval by TPD with clinical data.	II- $450 III - $7477 IV - $24345	Manufacturers and healthcare facilities report incidents to TPD. SSRs published by Health Canada.

Table 1. Summary of medical device regulatory agencies' policies (Brown II, 2020)

Policy Analysis

In order to conduct the analysis of policy, the criteria for evaluation were first determined. The first criterion is the effect public health as a function of how devices are classified and how strict the application requirements are. The FDA has had a history of devices which were wrongly classified due seemingly to a lack of strictness in policy. Zuckerman, Brown, and Nissen found that in 2009, two-thirds of recalled medical devices were cleared through the 510(k) process (Zuckerman, Brown, & Nissen, 2011). One of their final suggestions was that the FDA strengthens their use of special controls for 510(k)-cleared devices such as performance standards and general guidance documents.

The second criterion is the effect on public health as a function of the involvement of different stakeholders in the evaluation of device safety. Involving different stakeholders in the process of allowing medical devices to be marketed is paramount when dealing with the safety of a device. Not only should the governing body have controls set in place to prevent devices from entering markets, but they should be able to monitor them after they have been sold. Including end-users, healthcare professionals, and professional societies can improve public health by spreading knowledge of device faults and failures through as large a network as possible (Feldman et al., 2007).

The third criterion is the cost associated with registering a device. High costs act as a barrier to manufacturers who want to put their device on the market. New and innovative devices may greatly improve on those being sold at a given time, but they must be able to first enter the market. Table 2 assesses the different policies against the criteria.

Criteria	Public Health Impact: Strictness of Policy	Public Health Impact: Involvement of Stakeholders	Economic Impact: Cost to Manufacturer
Scoring Definition	Low – allows multiple pathways for device approval Medium – allows for one pathway for approval High – one approval pathway; provides subclasses	Low – low outreach for safety reporting Medium – medium outreach for safety reporting High – high outreach for safety reporting	Low – highest submission cost >$100k Medium – highest submission cost submission cost $10k-$100k High – highest submission cost > $10k
FDA	Low	Low	Low
PMDA	High	Low	N/A – Insufficient data
SAHPRA	Medium	N/A – Insufficient data	N/A – Insufficient data
TPD	Medium	High	Medium

Table 2: Policy analysis table using template from Center for Disease Control (Brown II, 2020)

Discussion

The case studies identified earlier in the research paper provide the justification for the need FDA policy reform. I have outlined potential alternatives to policy, identifying the Canadian system of medical device regulation to be the most suitable complete replacement. The most important sociotechnical aspect of this policy is its openness to the input of stakeholders. Medical devices are used by healthcare professionals to complete the work of diagnosing and treating patients. Health Canada's expansion of their post-marketing surveillance to require hospitals, long term care facilities, and private clinics to report device failures brings the latter into the network of the device. This larger network in turn promotes the health of the public –

more interactions creates a larger need for safety and efficacy of devices, and a larger number of users increases the number of reports that a device may receive. Those devices which encode safety into their design will be the devices which have the highest success when they enter the market, and public health will benefit as a byproduct of these report. Through requiring healthcare facilities to report failures, and educating them on failure detection methods, Health Canada's policy embodies aspects of both ANT and TIP. Specifically, they describe of a program and antiprogram of action for devices approved through them and put their focus on informing others health benefits for each technology.

The addition of mandatory reporting by healthcare facilities also has an effect on power dynamics. Because they are compelled to be involved in reporting device incidents, these facilities are more participative in local and state government. By reporting, users, healthcare professionals, and hospital-like institutions are given the power from their governing body to determine what medical devices stay on the market. The education of the different stakeholders on best practices of a given medical device is therefore of the utmost importance. By further interconnecting these different stakeholders, technology is enabled to better succeed in the existing network, as discussed by Cresswell, Worth, & Sheikh (YEAR).

Limitations

The scope of this research project was limited in multiple ways. The policy analysis included the policies of only four different nations. Of the chosen nations, three of them are first-world countries, defined by their relatively stable economies, high gross domestic product, and high standard of living. Their status as a first-world country does not invalidate the results of the study, though it is a limiter. There are many more nations to choose from, with policies differing

greatly from these. For the sake of simplicity, background literature did not include classifications for in-vitro diagnostic devices (IVDD) intended to diagnose conditions. These devices are usually special cases and include different types of reagents.

The policy analysis suffered from an incomplete set of data, and some areas of Table 1 and Table 2 were left blank as a result. Some information, such as submission costs for specific devices, as well as the cost of licensing were not able to be found or were not available to the average consumer. I suspect that manufacturers may have the ability to obtain a quote for some submission costs directly from the agencies. Documentation for the PMDA and SAHPRA was not as consolidated as that of the FDA and Health Canada, and some information was found in archives containing information that may not necessarily be reflective of 2020 policies.

Future Research and Significance

The first step I would take if I were to continue work on this research in the future is to expand the number of countries whose policies I analyze. I would include IVDDs as well in order to get a broader picture of the regulation policies. Additionally, I would need to research more methods of implementation for policy change in the United States. This would include cost-benefit analyses, an action plan, and a deeper analysis of how each stakeholder identified would be affected by such a change.

As a biomedical engineer, it is extremely important that I know how medical devices are regulated where I plan to practice. I plan to one day design prosthetic devices, so I will need to create detailed schematics and technical reports for my devices, keep detailed records on safety and effectiveness, and submit approval for my devices to the FDA. The ability to compile and review literature to conduct a policy analysis is useful in that I will be more suited to adapt my

project dossiers to fit with different policies if I were to move to another country or to market my device internationally.

Conclusion

This research identified a single possible total alternative for the FDA's policy on medical device regulation: Health Canada's policy. Before even considering new policy, one must provide a large set of evidence pointing to a need for reform. A change in policy has largely different short and long-term outcomes that one must attempt to predict when choosing a new policy. Implementation is not a simple task, and the costs associated with changing a policy may not outweigh the benefits of the policy. The impacts of new policy are best understood when examining the sociotechnical dimensions of medical technologies (who will be affected and how), the past and present state of the political environment of the country seeking to change the policy, and the feasibility of implementing the new policy. No single policy for medical device regulation will ever be able to cover every problem that may arise, so one must consider the trade-offs of every policy which they identify and consider every option that arises.

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