HOW DO DIFFERENT ACTORS IN THE MEDICAL NETWORK CONTRIBUTE TO OVER-IMAGING?

A Research Paper submitted to the Department of Engineering and Society
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Biomedical Engineering

By

Aarthee Baskaran

March 28, 2022

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.

ADVISOR
Catherine D. Baritaud, Department of Engineering and Society

QUALITY TESTING OF UTLRASOUND IMAGING DEVICES

Ultrasound imaging procedures lie on a spectrum between no imaging guidance to full interventional guidance techniques; both ends carry their own pros and cons. Currently, doctors are forced to evaluate risks and account for pain management, along with patient considerations, when ordering certain types of imaging for patients (Committee on Diagnostic Error in Health Care, 2015). This struggle is in part due to the large number of available tests and current gaps in teaching from medical schools. For example, lumbar epidural injections can be performed blindly or with CT fluoroscopic guidance (Wagner, 2004); the former has an increased chance of inaccurate injections and patient pain. Guided injections, albeit ensuring more accurate needle placements and less pain, may not be recommended because of time, radiation dose, low accessibility, and cost (Daniels, 2018). Rivanna Medical, an ultrasound imaging company, is working to create an intermediary device that can produce effective and robust 3D images that do not require too interventional of a procedure. The translational function of the device will allow different medical specialties to take advantage of the device's imaging capabilities. By finding a balance between imaging guidance and accuracy, ultrasound imaging can become a more accessible and safer option for patients.

The overall objective of the technical capstone is to assist in the development of a 3D ultrasound imaging. The information below was provided to us by our technical advisor, Zachary Leonard; the team comprised of myself, Shipra Trivedi, Sarah Abourakty, and Sarah Ames. This objective will be accomplished by evaluating the product reliability and efficacy via test fixtures, that we develop, and subsystem compatibility. The team is expected to develop a test fixture for the motors on which the image-capturing arrays will be performing the sweeps. This fixture will need to evaluate the performance and reliability of the fixture assembly by assessing factors such

as noise, friction, and flex durability. Additionally, the team will develop and evaluate various subsystems of the ultrasound imaging device to ensure high product reliability. Subsystems such as the acoustic coupling fluid system and flex circuit, will be integrated into the device design; the team is expected to optimize subsystem design or choose the best one based on overall compatibility, use-life, and function. The design specifications for the test fixtures will depend on the intended use of the device.

The above objectives will be achieved through external resources (experts in the field), individual research, and in-lab testing. Most Rivanna employees specialize in motor hardware, imaging mechanics, and test fixture design; their feedback and guidance will help focus and shape our individual efforts. Most of the rationale behind our work will rely on research in certain programming software, such as Arduino or NanoJ, motor mechanics, and design considerations; the research will not only improve our understanding but also reveal what others have done in the past and what techniques have provided the best results. Finally, we will be able to put our rationales or ideas into practice by testing with the equipment such as experimenting the various fixture assemblies in different orientations. Current available resources are all the necessary equipment such as motor types, 3D printers, all necessary wirings, sodder tools, etc.

The main motivation behind this technical capstone is to make the ultrasound imaging procedure easier for physicians to execute and to be more accessible for patients. By improving the usability of the device, it is important to consider if it will lead to the overutilization of its diagnostic tests. It raises the question: does optimizing the accessibility of an imaging device design increase the risk of it contributing to over-imaging

THE DRASTIC INCREASE IN IMAGING PROCEDURES

In 2006, 380 million radiologic procedures and 18 million nuclear medicine procedures were performed in the US; this volume accounts for nearly one-half of the worldwide nuclear medicine procedural use while US patients only comprise of 4.6% of the global population (Crownover & Bepko, 2013, p. 494). The drastic increase in imaging procedures can be associated with the sixfold increase in annual per capita radiation exposure. This downstream increase in exposure to radiation is a great cause for concern on patient safety and has normalized more intensive risk analysis of incorporating imaging into treatments. Additionally, the excessive use and waste of imaging technology and equipment places severe financial burdens on overall healthcare costs (Litkowski, 2016, p. 1132).

One aspect considered in the risk analysis is the necessity of the imaging procedure. Medical professionals from the University of Michigan have investigated the prevalence of over-imaging and how modern society has encouraged this shift (Joy, 2016). Over-testing in low-risk populations can return false positives, detect benign irregularities, and waste unnecessary resources and money. Additionally, the pressure from different actors in the medical network, such as insurance companies and general vs. specialized practitioners can enable unnecessary imaging (Livingston, 2017).

Medicine is slowly shifting towards a patient-centered care, working towards not only diagnosing and treating any illnesses but also considering patient comfort, emotional/mental health, and any minor risks. It's important to value the patient as a human and not view them as a problem that needs to be solved. However, with so many different actors in the medical network, varying in priority and importance, it is easy for the patient focus to be lost behind other facets

such as over-reassurance under the guise of maximizing patient survival or optimizing resource usage while minimizing unnecessary waste. The focus of this research paper is on identifying different actors in the medical network as contributors or curbing agents to over-imaging. The Actor Network Theory framework is used to analyze how curbing agents counter contributors to reduce imaging overuse.

The technical focus of the capstone project is evaluating product reliability and efficacy by assessing different subsystems of an imaging device that falls intermediary on the above-mentioned imaging spectrum. The STS focus of this research paper concentrates more on analyzing how relationships between different actors curb or contribute to over-imaging. The two topics are tightly coupled as they address different aspects of diagnostic imaging use. The former focuses on accessibility through device efficacy while the latter focuses on the relationship between technology accessibility and the medical network.

ISSUES PERPETUATING OVER-IMAGING

THE ROLE OF PHYSICIANS

Pressure on medical professionals to undergo imaging procedures continues to instigate this issue. Physicians struggle in finding a balance between providing "optimal and compassionate medical care on the one hand, while limiting the unnecessary use of resources on the other" (Litkowsky, 2016, p. 1132). In 2009, The American Board of Radiology Foundation held a summit in Washington DC and identified several factors that can encourage doctors in the overutilization of imaging services such as radiologists, defensive medicine, and self-referral.

Relationship with Radiologists

Physicians' working relationships with radiologists can also strongly encourage or influence them to overprescribe imaging tests. Although radiologists cannot realistically be expected to thoroughly investigate each imaging request by referring physicians, they play a crucial and momentous role in a physician's decision-making process for imaging requests. Radiologists may fail to thoroughly analyze or review requested examinations for appropriateness; this is primarily due to their heavy workload and insufficient patient information. Additionally, if they are trying to maintain strong rapport with fellow physicians, they feel uncomfortable acting as a gatekeeper of radiologic procedures (Kilani, 2011). Instituting requirements that prevent radiologists from acting as consultants and require them to approve studies that may include advanced technologies or subject patients to higher radiation risk can reduce the overutilization of imaging. Radiologists may approve of additional imaging tests because of clinical protocols or due to lack of confidence in a diagnosis. Developing a way to verify that performing these scans is solely for the best interest of the patient is critical to reducing unnecessary imaging. Finally, it is important for radiologists to understand the weight and credibility of their recommendations as experts in the field; physicians may feel pressured to accept any suggestions, especially if motivated by defensive medicine.

Legal Climate

Defensive medicine is diagnostic or therapeutic measures taken with the intent to protect physicians from potential malpractice claims rather than to benefit the patient (Hendee, 2010). Doctors' main motivation for prescribing testing is fear or malpractice claims that a problem was overseen. Nearly 52% of the major reasons a doctor orders a test is malpractice concerns; this

way of thinking rivals the progressive shift toward patient-centered care (Joy, 2016). It is largely perpetuated by legal environments that encourage targeting healthcare providers with malpractice claims and is thought to be more significant in the United States as its legal environment is far more aggressive and predatory compared to other countries (Hendee, 2010). In one state, nearly 25% of advanced imaging tests were ordered because of defensive medicine, resulting in a cost of $1.4 billion per year (Hendee, 2010, p. 242). Since defensive medicine is not specific to imaging, it is difficult to quantify its contribution to overutilization costs; it is thought to be around 5% - 25% of total imaging costs. To mitigate the preservative mindset of the medical community, legislative steps should be put in place to protect health providers year (Hendee, 2010, p. 242).

Financial Motivations

Imaging has been one of the fastest growing contributors of healthcare costs in the United States (Kilani, 2011). National health expenditures grew from $1.4 trillion to $4.1 trillion from 2000 to 2020; health spending increased by 9.7% from 2019-2020 compared to a 4.3% increase from 2018-2019 (Kurani, 2022, para. 2). The US Department of Health and Human Services have determined that diagnostic imaging costs pose one of the most significant risks to the Medicare trust fund.

Self-referral is another significant contributor to physician based over-imaging; it is defined as imaging procedure referral where the referring physician, a non-radiologist, financially benefits from providing service (Hendee, 2010). This practice can be seen as a way for non-radiologists to increase their practice revenue (Kilani, 2011). This can cause a conflict of interest as the physician's financial motivation can predominate the procedure's necessity.

Nearly $16 billion a year are spent on avoidable imaging procedures caused by self-referrals. It was also shown that 81.8% of radiation doses delivered to patients occurred in outpatient offices which includes 44% in physician officers where self-referral typically takes place (Hendee, 2010, p. 242). A meta-analysis determined that non-radiologists self-referrers are 2.48 times more likely to order imaging than physicians with no financial gain from referral; this ultimately led to a 59% increase in imaging rate (Kilani, 2011, para. 15). Proponents of self-referral argue it increases convenience, speeds up the treatment timeline, and decreases cost by offering same-day imaging for patients (Sarma & Heilburn, 2012) (Kilani, 2011). However, the argument of correlating same-day imaging with convenience is faulty as it was found that same-day imaging only occurred in 15% of CT and MRI scans (Sarma & Heilburn, 2012, para. 19). Additionally, Hughes et al showed that in 13 medical condition-illness combinations, self-referral was not affiliated with shorter illness duration but with higher overall costs (Kilani, 2011, para. 19).

EMPOWERED PATIENT DEMAND

James Burke, a neurologist at the University of Michigan stated that nearly half of patients with migraines get unnecessary MRIs, a "pre-emptive action fueled by 'a culture where we like to be reassured'" (Joy, 2016, para. 6). This societal norm is difficult to diagnose because with more precise and advanced technology, it is difficult to not want to take advantage of those resources to ensure one's health is fully understood. Additionally, increased availability of more advanced diagnostic technologies has created a perception that imaging is a way of comforting patients, amplifying the benefits while overlooking the risks and costs (Salerno, 2019). Through media such as the Internet, patients can learn about the vast diversity of imaging tests that are available; however, these sources of information are typically not thorough and comprehensive.

The cost-benefit analysis is not sincerely explored in easily accessible research. For example, Joseph Steele, the division head of Clinical Operations of Diagnostic Imaging at MD Anderson, stated that the "concern is that some patients do not understand their own risk and may make poorly informed decisions — either for or against imaging — that may not be in their best interest" (Sussman, 2014, para. 30). He also stated a strong dichotomy between patients' comfort with radiation exposure; some are exceedingly fearful and reject necessary testing while others test as much as possible, disregarding cost-benefit analysis. These mindsets stem from a place of ignorance and medical anxiety and can only be resolved by improving patient-doctor communication and patient education. One issue with this solution is that the current payment system in health institutions do not encourage physicians to properly educate patients on imaging (Hendee, 2010).

POORLY DISSEMINATED IMAGING STANDARDS

The lack of standard protocol and appropriateness criteria for performing risk-benefit analysis for diagnostic imaging is a major contributor to the over-prescription of tests by physicians. As explained earlier in the thesis, radiologists may not fully assess if a request is fully qualified against an appropriateness criterion (Hendee, 2010). The use of criteria is voluntary and is typically based on consensus of expert opinions rather than objective medical evidence and comparative effectiveness research. Awareness of this criteria is not widespread resulting in the neglect of incorporating these standards into common practice. Comparative effectiveness research should be the basis of an appropriateness criteria; it is research that objectively compares results from different approaches on handling diseases. Although there are active studies, it is not a priority in the diagnostic community and should be focused on as a "deterrent to overutilization of medical services" (Hendee, 2010, p. 242). Standards such as these

need to be more frequently updated and integrated into physician's workflow to ensure a holistic, ethical treatment for patients.

ACTORS CURBING OVER-IMAGING

Some actors, such as the Internet, patient expectations, hospital systems, and financial incentives encourage over-imaging; however, there are other entities that are working to curb imaging rates to improve patient care and reduce the financial burden on the healthcare system.

Insurance Companies

Multiple articles have described the ongoing conflict between how insurance companies and hospitals handle imaging finances and how those policy changes affect patients (Litkowski, 2016) (Livingston, 2017). For example, due to hospitals overcharging, Anthem changed their insurance policy so that they would not cover any imaging cost that were performed at a hospital unless they were deemed necessary; hospitals tend to overcharge for imaging to make up for other financial losses (American Health Imaging, 2018). The policy was intended to encourage testing to occur in imaging centers rather than hospitals as they are cheaper (Sculley, 2018). Additionally, another strategy done by insurance providers is prior authorization, which means physicians need to obtain approval before ordering tests (Litkowski, 2016). These requests are reviewed by benefits managers who score them against appropriateness guidelines. Some have argued this approach generates more administrative work and constrains physician autonomy.

Medical Societies

Medical societies such as the American College of Radiology (ACR) are actively working to develop and implement better regulatory standards for physicians to discourage over-imaging. For example, in 2010, the ACR, the Radiological Society of North America (RSNA), the American Association of Physicists in Medicine (AAPM), and the American Society of Radiologic Technologists (ASRT) launched the Image Wisely campaign with the intention of reducing the amount of radiation used in both essential and unnecessary tests (Brink & Amis, 2010, p. 601). There were around 70,000 pledges to the campaign in early 2017 (Hernanz-Schulman, 2017, para. 6). It was also shown in an evaluation of health institutes before and after implementing the campaign that CT imaging rates decreased from 70% in 2004 to 56.1% in 2014 (Fernandes et al, 2016, para. 16). However, since these campaigns are voluntary, it is hard to sincerely integrate into a physician's work ethic. For example, the Choosing Wisely campaign, launched in 2012 by the American Board of Internal Medicine, recommended against routine imaging for nonspecific back pain; however, it was shown that 36% of family practitioners and 13% of general internists routinely image patients with those issues (Litkowski, 2016, p. 1133).

Legislation

Finally, although legislative actions were developed with the expectation of inhibiting the unethical practice of self-referrals, they ultimately increased imaging utilization once implemented. For example, the 2007 Deficit Reduction Act made across-the-board cuts in imaging reimbursement and caused 12.7% reduction in Medicare imaging expenditures (Kilani, 2011). However, self-referrers were able to order more imaging to reach internal billing targets. It was shown that two years after this act was implemented, Medicare payments for imaging

were 4% higher for non-radiologists than payments for radiologists; radiologists, typically, do not have the ability to self-refer (Kilani, 2011, para. 21). Another example of legislative is the Stark's Law developed by the Center for Medicare and Medicaid Services (CMS) and issued on November 20, 2020 (CMS, 2021). This law prohibits physicians from referring imaging services from an entity that they have a financial relationship with. It is expected to improve the quality of care patients receive and ensure they are offered a treatment plan that is solely based on their best interests.

ANALYSIS OF RELATIONSHIPS BETWEEN CONTRIBUTORS AND CURBING AGENTS

In developing this thesis and investigation, many stakeholders and actors in the medical network were identified: the Internet, insurance companies and their policies, the general public's perspective of medicine, hospital systems, physicians, medical societies, and more indirect influencers. To better understand active efforts to curb over-imaging and their shortcomings, the inter-actor relationships

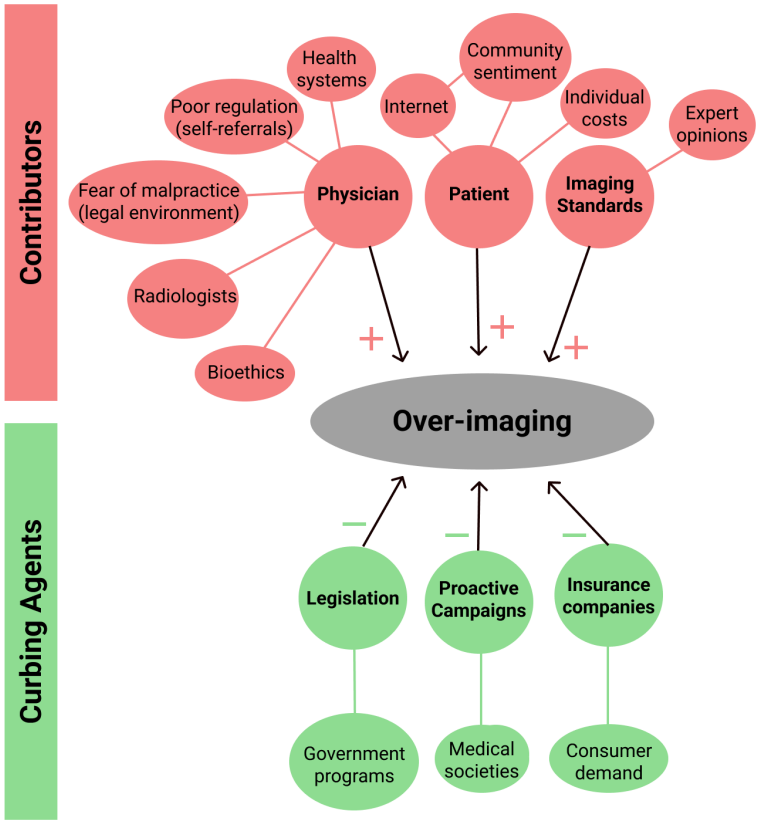

Figure 1: Actor network theory model of medical network: Visualization of different actors (Baskaran, 2022)

are analyzed. Figure 1 effectively demonstrates how both indirect and direct actors either contribute or curb over-imaging. Physicians, patients, and current imaging standards contribute the most to over-imaging; physicians have the most weighted contribution as experts in the field and are impacted by financial, legal, and bioethical factors. As discussed earlier, the defensive medicine mindset encourages physicians to make decisions from a place of fear of malpractice rather than patient's best interest; along with the lucrative reimbursement and self-referral opportunities and poor regulation, physicians are more incentivized to order imaging. Additionally, contributing actors interact with each other such as the Internet influencing the community perspective on imaging and health systems impacting both physicians' decision making from a financial and procedural perspective.

The curbing agents work to reduce over-imaging through policies and campaigns, as depicted in Figure 2. Policies by insurance companies work to ultimately reduce patient individual costs by reducing the overall financial return health systems gain from imaging procedures. Additionally, since the public is slightly removed from the medical network, they only sincerely interact with the physician, insurance provider, and community. If large insurance providers are instituting policies that directly impact their clients in regards to accessibility to imaging, the community may gain more awareness of over-imaging and make more informed decisions. Additionally, legislative acts target issues that impact over-imaging behavior such as mitigating fear of malpractice by instituting policies that will protect physicians

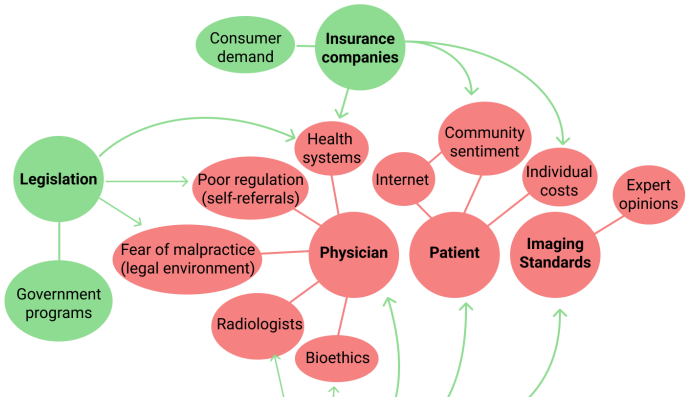

Figure 2: How curbing agent actors target contributor actors to reduce over-imaging (Baskaran, 2022).

and implementing regulatory standards to prevent inappropriate use of self-referral. Finally, proactive campaigns, although more voluntary and awareness-based, work to better educate the medical community on over-imaging. Although, radiologists are the experts in the diagnostic field, updating appropriateness criteria and educating physicians and patients, can ensure more actors are behaving responsibly. To fully address this issue, the network needs to work less as a group of silos where each actor is solely operating with knowledge from their field. Making informed and responsible decisions means having a well-rounded, holistic approach where actors are working with each other than against.

POTENTIAL HOLISITIC APPROACH

The overall solution derived from this thesis is to model efforts based off the curbing agents but modify based on where they were unsuccessful. An approach that incorporates legislation, insurance policies, and proactive campaigns is a holistic method that addresses all current fallibilities. The issue with proactive campaigns is that they are primarily voluntary and poorly disseminated. Only 42% of physicians in 2017 had heard about the Choosing Wisely campaign (Patashnik, 2017). Future campaigns need to be more aggressively integrated by earning stronger credibility and agency, and shared at medical school, residency programs, hospitals, and private practices. Integration can also be incentivized by offering an accreditation like ABET for medical institutions. This will also improve the connectivity and bidirectionality of the network to operate less like individual silos. Additionally, mentioned earlier, issues with prior legislation were that it did little to curb self-referral costs. Non-radiologists have more opportunity to self-refer; therefore, legislative acts need to be designed to target non-radiologists self-referrals instead of making across-the-board cuts as the 2007 Deficit Reduction Act. A

potential limitation to this approach is that it can increase the administrative workload and burden for physicians, ultimately reducing the quality of care they are able to offer patients. Future research for this thesis would include looking further into the politics of insurance policies and directly how they impact health systems to develop suggestions for future policies.

REFERENCES

American Health Imaging. (2018, April 6). Insurance companies cracking down on hospitals for diagnostic imaging cost. *American Health Imaging* https://americanhealthimaging.com/blog/insurance-hospitals-diagnostic-imaging-cost/

Baskaran, A. (2022). *Actor network theory model of medical network: Visualization of different actors*. [1]. *STS Research Paper:* How do different actors in the medical network contribute to over-imaging (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA

Baskaran, A. (2022). *How curbing agent actors target contributor actors to reduce over-imaging*. [2]. *STS Research Paper:* How do different actors in the medical network contribute to over-imaging (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA

Brink, J., & Amis, S. (2010, December 1). Image wisely: A campaign to increase awareness about adult radiation protection. *Radiology*. *257*(3), 601-602. https://doi.org/10.1148/radiol.10101335

Committee on Diagnostic Error in Health Care. (2015, December 29). Improving diagnosis in health care. *NCBI*. https://www.ncbi.nlm.nih.gov/books/NBK338593/

Cressman, D. (2009, April). A brief overview of Actor-Network Theory: Punctualization, heterogenous engineering, & translation.

Crownover, B., & Bepko, J. (2013). Appropriate and safe use of diagnostic imaging. *American Family Physician*, *87*(7), 494–501. https://www.aafp.org/afp/2013/0401/p494.html

Daniels, E. W., Cole, D., Jacobs, B., & Phillips, S. F. (2018, February 1). Existing evidence on ultrasound-guided injections in sports medicine. *Orthopaedic Journal of Sports Medicine, 6(2),* 232596711875657. https://doi.org/10.1177/2325967118756576

Fernandes, K., Levin, T., Miller, T., Schoenfeld, A., & Amis, S. (2016, August). Evaluating an image gently and image wisely campaign in a multihospital health care system. *Journal of the American College of Radiology, 13*(8), 1010-1017. https://doi.org/10.1016/j.jacr.2016.04.025

Hendee, W. R., Becker, G. J., Borgstede, J. P., Bosma, J., Casarella, W. J., Erickson, B. A., … & Wallner, P. E. (2010, October 10). Addressing overutilization in medical imaging. *Radiology, 257(1),* 240-245. https://doi.org/10.1148/radiol.10100063

Hernanz-Schulman, M. (2017, February). Pediatric CT and image gently. https://www.imagewisely.org/Imaging-Modalities/Computed-Tomography/Pediatric-CT-and-Image-Gently

Joy, K. (2016, October 13). Unnecessary medical tests: Overuse of medical tests and screening. https://labblog.uofmhealth.org/industry-dx/to-screen-or-not to-screen-risks-of-over-imaging-and-testing

Kilani, R. K., Paxton, B. E., Stinnett, S. S., Barnhart, H. X., Bindal, V., & Lungren, M. P. (2011, July). Self-referral in medical imaging: A meta-analysis of the literature. *Journal of the American College of Radiology, 8(7),* 469-476. https://doi.org/10.1016/j.jacr.2011.01.016

Kurani, N., Ortaliza, J., Wager, E., Fox, L., & Amin, K. (2022, February). How has the U.S. spending on healthcare changed over time. https://www.healthsystemtracker.org/chart-collection/u-s-spending-healthcare-changed-time/

Litkowski, P. E., Smetana, G. W., Zeidel, M. L., & Blanchard, M. S. (2016, October 1). *The American Journal of Medicine*, *129(10)*, 1131–1135. https://doi.org/10.1016/j.amjmed.2016.06.020

Livingston, S. (2017, August 31). Anthem's new outpatient imaging policy likely to hit hospitals' bottom line. *Modern Healthcare*. https://www.modernhealthcare.com/article/20170826/NEWS/170829906/anthem-s-new-outpatient-imaging-policy-likely-to-hit-hospitals-bottom-line

Patashnik, E. M., & Dowling, C. M. (2017, November 7). Realizing the promise of choosing wisely will require changes both in the culture of specialty societies and in public policy: *Health Affairs Forefront.* https://www.healthaffairs.org/do/10.1377/forefront.20171107.649027/full/

Salerno, S., Laghi, A., Cantone, M.-C., Sartori, P., Pinto, A., & Frija, G. (2019, March 21). Overdiagnosis and overimaging: An ethical issue for Radiological Protection. *La Radiologia Medica, 124(8),* 714-720. https://doi.org/10.1007/s11547-019-01029-5

Sarma, A. & Heilburn, M. (2012, April). A medical student perspective on self-referral and overutilization in radiology: Application of the four core principles of medical ethics. *National Library of Medicine, 9(4),* 251-251. https://pubmed.ncbi.nlm.nih.gov/22469375/

Scully, M. (2014, September 4). Industry voice – prior authorizations frustrate physicians. In

radiology, denials can be life-threatening. https://www.fiercehealthcare.com/practices/industry-voices-prior-authorizations-frustrate-physicians-radiology-denials-can-be-life

Sussman, L. (2014, April 28). Understanding over-imaging. *MD Anderson Cancer Center*. https://www.mdanderson.org/publications/conquest/understanding-over-imaging.h37-1589046.html

Wagner, A. (2004, November 25). CT fluoroscopy-guided epidural injections: Technique and results. *25(10)*, 1821-3. https://pubmed.ncbi.nlm.nih.gov/15569755/