TELERADIOLOGY:

Current and Future Market Trends

Arvind Veluvali

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1: INTRODUCTION

Teleradiology is defined[1] as "the electronic transmission of diagnostic imaging studies from one location to another for the purposes of interpretation and/or consultation." Despite having been around since the 1960s[2], teleradiology has been growing increasingly prominent in recent years. The purpose of this report is to examine the current state of the market for teleradiology, as well as to analyze the potential of this technology in the market.

[1] Binkhuysen, F., & Ranschaert, E. (2011, May 1). Teleradiology: Evolution and concepts. *European Journal of Radiology*, *78*(2). doi:https://doi.org/10.1016/j.ejrad.2010.08.027

[2] Bashshur, R. L., Krupinski, E. A., Thrall, J. H., & Bashshur, N. (2016). The Empirical Foundations of Teleradiology and Related Applications: A Review of the Evidence. *Telemedicine journal and e-health : the official journal of the American Telemedicine Association*, *22*(11), 868–898. https://doi.org/10.1089/tmj.2016.0149

2: MEDICAL NEED

There are several areas of medical need for which teleradiology is a compelling candidate.

First, US hospitals, particularly in rural counties, are understaffed by specialists in general, but especially by radiologists[3]. According to Dr. Andrew Rosenkrantz, a radiologist at NYU Langone Medical Center, "Counties that are poor and rural are less likely to have access to a radiologist who accepts Medicare patients than counties that are richer and urban. These same counties are also less likely to have access to subspecialized radiologists...[It has been] previously suggested that geographic redistribution may be at least a partial solution to current radiologist workforce disparities. However, even with redistribution, the total supply of subspecialist radiologists may not be sufficient to achieve widespread geographic coverage."

This problem is not unique to the United States, either. In rural and remote areas of the globe, specialists are few and far between[4]; these rural areas are far from clinical centers where specialists reside, and transportation to these centers is difficult[5]. Density of specialists is highly correlated with physician density, which varies widely between developed and developing nations. According to a 2012 report by the World Health Organization, there were "3.180 physicians per 1000 people in France, 1.132 physicians per 1000 people in Peru, 0.204 physicians per 1000 people in Indonesia, and 0.04 physicians per 1000 people in Mozambique."[6]

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[3] Yee, K. (2018, January 5). Geography, lack of specialization hinder imaging access. In *AuntMinnie*. Retrieved from https://www.auntminnie.com/index.aspx?sec=sup&sub=imc&pag=dis&ItemID=119524

[4] Khodaie, M., Askari, A., & Bahaadinbeigy, K. (2015). "Evaluation of a very low-cost and simple teleradiology technique". *Journal of digital imaging*, *28*(3), 295–301. https://doi.org/10.1007/s10278-014-9756-2

[5] Tianyu L, Zixiang X, Yun DY. Compression techniques in tele-radiology. *ProcSPIE.* 1999;3808:792–800.

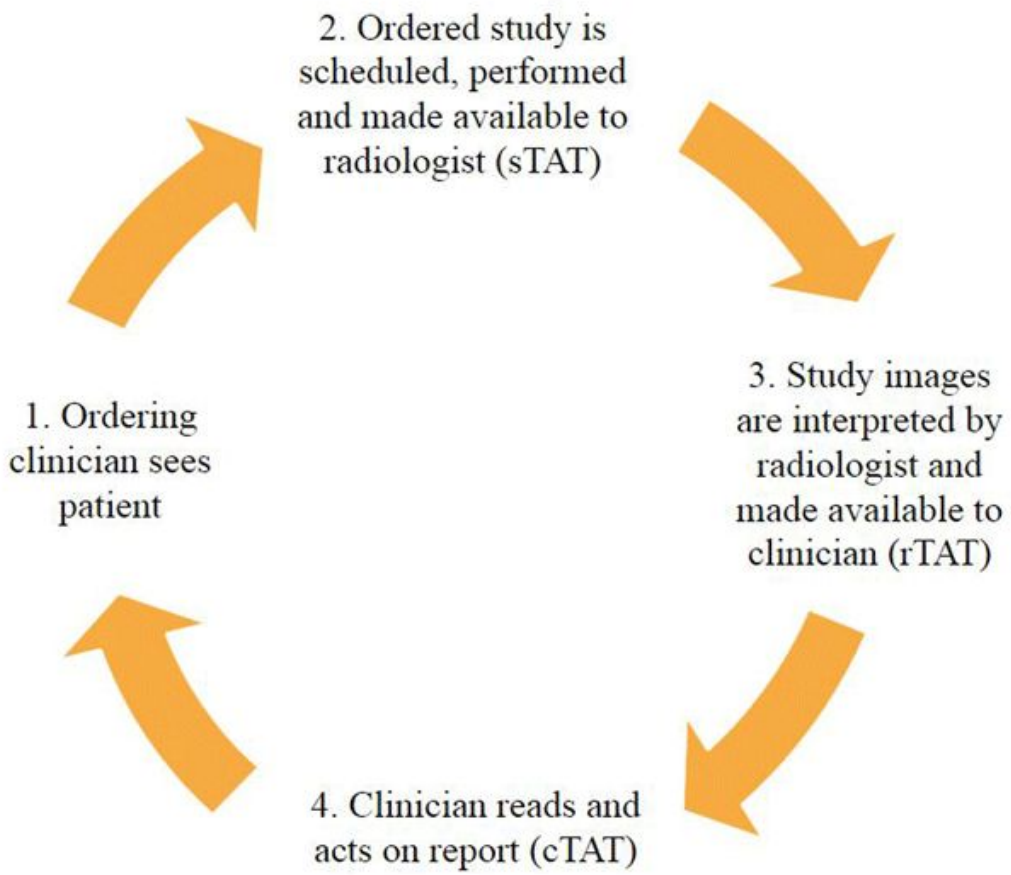
[6] Density of Physician, World Health Organization (WHO), http://www.who.int/en

Second, turnaround times are long. Radiologists are often overwhelmed by a "catch-all" approach, where a single radiologist is expected to assess all body systems due to the unavailability of specialists within his or her hospital system. Not only does lead to worse patient outcomes since patients are being seen by non-specialized radiologists[7], wait times, especially radiology report turnaround times (rTAT), are high. According to Dr. Andreas Zabel, writing in *Insights into Imaging*, a radiology trade publication under the Springer umbrella, rTAT is 1051 minutes for MRIs and 278 minutes for radiographs, with an average rTAT for major hospitals of 288 minutes and for minor hospitals of 300 minutes[8]. Given that rTAT only reflects the radiologist's analysis, and not the time taken for the clinician to order the report, the study to be scheduled, the patient to go in for imaging, and the ordering clinician to read and act on the radiologist's report (as seen in Figure 1), patients could be waiting for weeks for results.

[7] Eakins, C. (2012, October). Second Opinion Interpretations by Specialty Radiologists at a Pediatric Hospital: Rate of Disagreement and Clinical Implications. *American Journal of Roentgenology*. Retrieved from https://www.ajronline.org/doi/full/10.2214/AJR.11.7662

[8] Zabel, A.O.J., Leschka, S., Wildermuth, S. *et al.* Subspecialized radiological reporting reduces radiology report turnaround time. *Insights Imaging* 11, 114 (2020). https://doi.org/10.1186/s13244-020-00917-z

Fig. 1: The workflow associated with radiological imaging[9].



[9] Mayer, M., & Sebro, R. (2019). An Important and Often Ignored Turnaround Time in Radiology – Clinician Turnaround Time: Implications for Musculoskeletal Radiology. *Journal of the Belgian Society of Radiology*, *103*(1), 49. DOI: http://doi.org/10.5334/jbsr.1834

3: CURRENT STATE OF THE MARKET

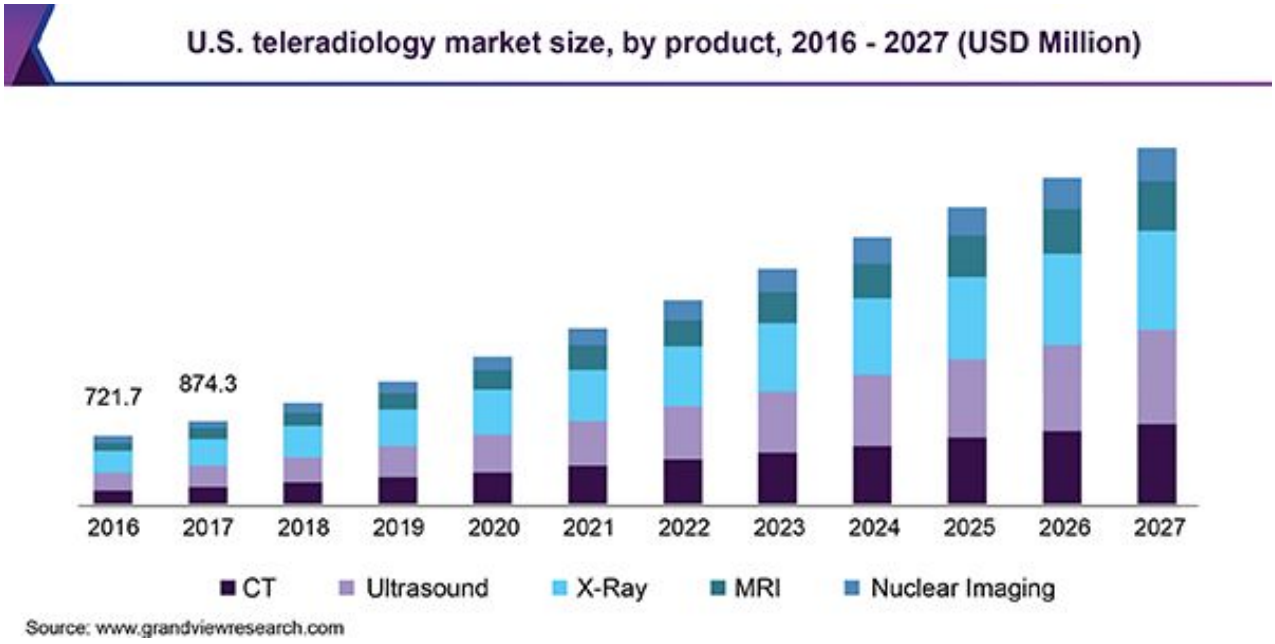
Teleradiology is fairly common. According to a survey of radiologists conducted by the American College of Radiology[10], "Among 731 of 936 respondents who indicated a non-teleradiologist primary work setting, 85.6% reported performing teleradiology within the past 10 years and 25.4% reported that teleradiology represents a majority of their annual imaging volumes; 84.4% performed teleradiology for internal examinations and 45.7% for external examinations; 46.2% performed teleradiology for rural areas and 37.2% for critical access hospitals; 91.3% performed teleradiology during weekday normal business hours and 44.5% to 79.6% over evening, overnight, and weekend hours."

According to Grandview Research[11], the global teleradiology market size was $3.6 billion in 2019, with a compound annual growth rate (CAGR) of 13.9%. Grandview has forecasted that the global teleradiology market will reach a size of $24 billion by 2027 (Figure 2).

[10] Rosenkrantz, A., Hanna, T., Steenburg, S., Tarrant, M., Pyatt, R., & Friedberg, E. (2019, July 1). The Current State of Teleradiology Across the United States: A National Survey of Radiologists' Habits, Attitudes, and Perceptions on Teleradiology Practice. *Journal of the American College of Radiology*, *16*(12). doi:https://doi.org/10.1016/j.jacr.2019.05.053

[11] GrandView Research. (2020). *Teleradiology Market Analysis Report By Product (Ultrasound, MRI, CT, X-ray, Nuclear Imaging), By End Use (Hospital, Ambulatory Imaging Center, Radiology Clinics), By Region, And Segment Forecasts, 20*. Retrieved from https://www.grandviewresearch.com/industry-analysis/teleradiology-market#:~:text=Report%20Overview,rendering%20drivers%20of%20the%20market.

Fig. 2: The growth of the US teleradiology market.[12]



The teleradiology market, both in the United States and abroad, is expected to grow dramatically in the coming years. Key factors driving this growth include the integration of artificial intelligence (AI) analysis systems into teleradiology; growing acceptance[13] of Picture Archiving and Communication Systems (PACS), which allow easy transfer of digital medical images; and growing investment and interest in telehealth in general in the wake of the COVID-19 pandemic. According to Frost & Sullivan, a research and insights firm, telehealth demand increased by

[12] GrandView Research. (2020). *Teleradiology Market Analysis Report By Product (Ultrasound, MRI, CT, X-ray, Nuclear Imaging), By End Use (Hospital, Ambulatory Imaging Center, Radiology Clinics), By Region, And Segment Forecasts, 20*. Retrieved from https://www.grandviewresearch.com/industry-analysis/teleradiology-market#:~:text=Report%20Overview,rendering%20drivers%20of%20the%20market.

[13] Duyck, P. (2008). User Acceptance of a Picture Archiving and Communication System: Applying the Unified Theory of Acceptance and Use of Technology in a Radiological Setting. *Methods of Information in Medicine*, *47*(2). doi:10.3414/ME0477

64.9% in 2020, with a projected market increase of 700% by 2025[14]. McKinsey & Company reports that the global telehealth market could ultimately reach $250 billion in size[15].

[14] Frost & Sullivan. (2020, May 13). Telehealth—A Technology-Based Weapon in the War Against the Coronavirus, 2020. In *Frost & Sullivan*. Retrieved from https://ww2.frost.com/news/press-releases/telehealth-to-experience-massive-growth-with-covid-19-pandemic-says-frost-sullivan/

[15] McKinsey & Company. (2020, May 29). Telehealth: A quarter-trillion-dollar post-COVID-19 reality?. In *McKinsey & Company*. Retrieved from https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/telehealth-a-quarter-trillion-dollar-post-covid-19-reality#

4: KEY PRODUCTS UNDER DEVELOPMENT

As explained earlier in this report, teleradiology is already fairly common in the United States. Products under development in this area are mostly centered around improvements to existing technology: namely, the implementation of computer vision and artificial intelligence; and access-expanding technologies.

A: Computer Vision and Artificial Intelligence

Computer vision and artificial intelligence aims to completely disrupt the modern practice of radiology, augmenting or completely obviating the need for human radiologists. The use of AI in radiological applications is an incredibly frothy space; companies in this arena have raised hundreds of millions of dollars from venture capitalists and other investors[16]. At the Radiological Society of North America's annual conference in 2019, there were 136 AI-focused companies, with 38 of those companies being first-time exhibitors[17].

The rationale behind this technology is highly promising. AI promises to deliver better outcomes for patients, with the ability to analyze patterns that are far too subtle for human eyes to detect, including in ways that are not obvious to human radiologists. According to a report published in *Nature*[18], "Because they can process massive amounts of data, computers can perform analytical tasks that are beyond human capability. Google, for instance, is using its computing power to develop AI algorithms that construct two-dimensional CT images of lungs into a three-dimensional lung and look at the entire structure to determine whether cancer is present.

[16] Hall, C. (2020, September 16). Aidoc Adds $20M To Series B For AI-based Radiology Tools. In *Crunchbase*. Retrieved from https://news.crunchbase.com/news/aidoc-adds-20m-to-series-b-for-ai-based-radiology-tools/
[17] Shah, S. (2019, December 27). The Radiology AI Evolution at RSNA 2019. In *Imaging Technology News*. Retrieved from https://www.itnonline.com/article/radiology-ai-evolution-rsna-2019#:~:text=The%20AI%20showcase%20had%20136,which%20were%20first%2Dtime%20exhibitors.
[18] Reardon, S. (2019, December 18). Rise of Robot Radiologists. *Nature*. doi:https://doi.org/10.1038/d41586-019-03847-z

Radiologists, in contrast, have to look at these images individually and attempt to reconstruct them in their heads." Thus, in addition to its improved accuracy, AI has the potential to be far more efficient than human radiologists.

B: Access-Expanding Technologies

One of the largest issues in teleradiology is a lack of consistent information availability: of patient histories and charts, and especially of radiological images. Companies are aiming to solve this problem by creating servers and services that aim to consolidate radiological information so that clinics in different locations can operate off the same set of data and according to the same standards.

One such solution is the rise of Picture Archiving and Communication Systems (PACS), which allow easy transfer of digital medical images. While PACs have been around for decades now, they have been increasing in popularity in recent years. There are dozens of companies offering services around PACS and Vendor Neutral Archives (VNAs), which manage and store data (Figure 3). The leading companies in this market are shown in Table 1, below:

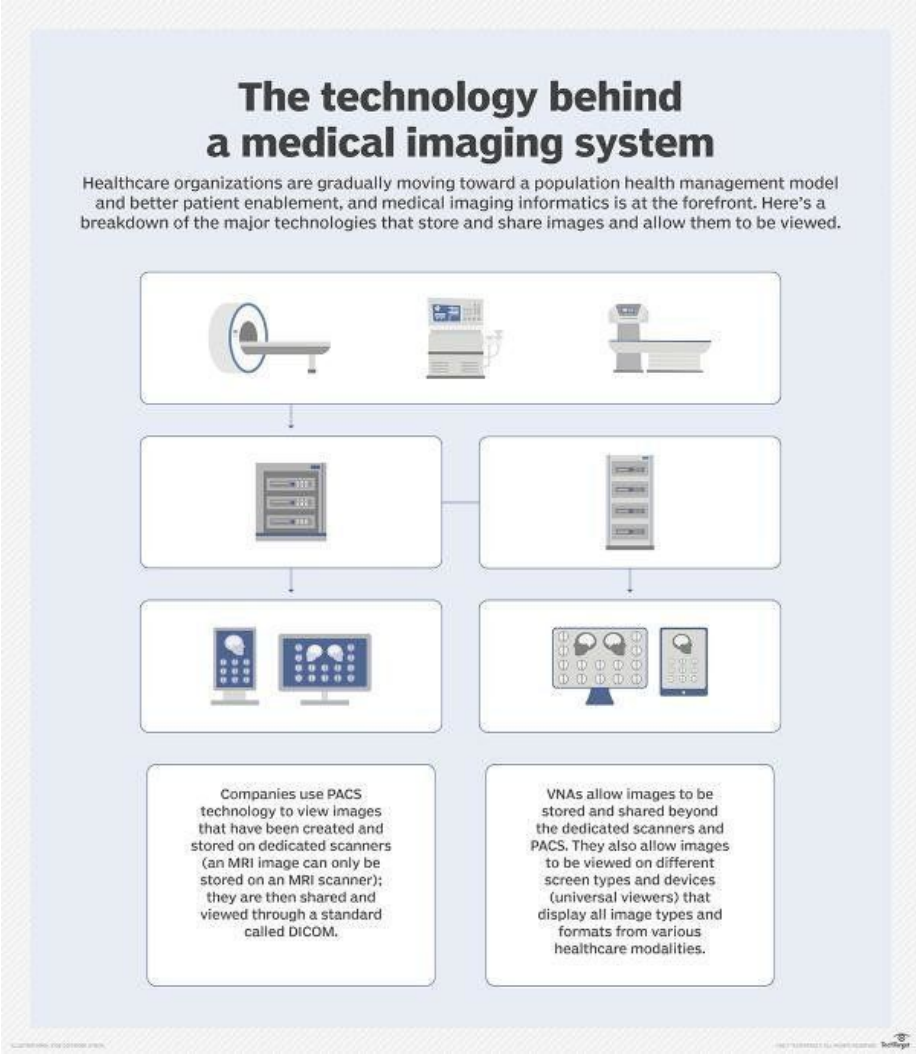
Table 1: Leading PACS/VNA Companies.[19]

Company	Founded	Location	Total Revenue
Agfa-Gevaert	1867	Mortsel, Belgium	€2.239Bn (2019)[20]
BridgeHead Software Limited	1994	Surrey, UK	$30M (2019)[21]

[19] Meticulous Research. (2021, February 10). TOP 10 COMPANIES IN VNA & PACS MARKET. In *Meticulous Research*. Retrieved from https://meticulousblog.org/top-10-companies-vna-pacs-market/
[20] AGFA Gaevert. (n.d.). Consolidated Statements of Income. In *AGFA*. Retrieved from https://www.agfa.com/corporate/investor-relations/key-figures/
[21] ZoomInfo. (n.d.). BridgeHead Software. In *ZoomInfo*. Retrieved from https://www.zoominfo.com/c/bridgehead-software-ltd/5506055

Carestream Health, Inc.	2007	Rochester, NY, USA	$1Bn (2019)[22]
FUJIFILM Medical Systems U.S.A., Inc.	1965	Milwaukee, WI, USA	$175.4M (2019)[23]
GE Healthcare	1994	Chicago, IL, USA	$19.9Bn (2019)[24]

Fig. 3: The uses of PACs and VNAs[25].



[22] ZoomInfo. (n.d.). Carestream. In *ZoomInfo*. Retrieved from https://www.zoominfo.com/c/carestream/50957775
[23] Dun & Bradstreet. (n.d.). Fujifilm Medical Systems U.S.A., Inc. In *Dun & Bradstreet*. Retrieved from https://www.dnb.com/business-directory/company-profiles.fujifilm_medical_systems_usa_inc.727b1e25e55374479a42de2099f23e61.html
[24] Statista. (n.d.). Revenue of General Electric Healthcare from 2008 to 2019. In *Statista*. Retrieved from https://www.statista.com/statistics/277734/revenue-for-general-electric-healthcare-segment-since-2008/
[25] Shacklett, M. E. (2017, November 17). A look at the leading medical imaging software on the market. In *TechTarget*. Retrieved from https://searchhealthit.techtarget.com/feature/A-look-at-the-leading-medical-imaging-software-on-the-market

5: KEY CHALLENGES AND OPPORTUNITIES

While teleradiology offers numerous compelling advantages over traditional, decentralized radiology, it still has several challenges that must be overcome. The three largest challenges[26], as well as potential solutions, are discussed in this section.

A: Challenges

1. Licensing and Credentialing

Within the United States, each state has individual requirements for teleradiologist licensing[27]. This means that teleradiology practitioners must be licensed to practice at the facility that is sending images and results, as well as the facility that is receiving them. This is not a problem when the teleradiologist is working with facilities located within the same state; however, most teleradiologists work across state lines. In a survey conducted among teleradiologists, 50.4% of them indicated that they wrote reports for states in which they did not have a license[28]. According to Hanna et. al[29], "These barriers result in practice inefficiencies and restricted access to emergent and subspecialty care, especially in rural markets."

Because licensure is ultimately a legislative issue, the best solution to this problem is through legislative action. Steps have been taken already to ameliorate the issues associated with

[26] Hanna TN, Steenburg SD, Rosenkrantz AB, Pyatt RS Jr, Duszak R Jr, Friedberg EB. Emerging Challenges and Opportunities in the Evolution of Teleradiology. AJR Am J Roentgenol. 2020 Dec;215(6):1411-1416. doi: 10.2214/AJR.20.23007. Epub 2020 Oct 14. PMID: 33052736.
[27] American College of Radiology. (n.d.). State Teleradiology Licensure Requirements. In *American College of Radiology*. Retrieved from https://www.acr.org/Advocacy-and-Economics/State-Issues/Licensure-Requirements
[28] Simon L, Friedland B. Interstate Practice of Dental Teleradiology in the United States: The Effect of Licensing Requirements on Oral and Maxillofacial Radiologists' Practice Patterns. Telemed J E Health. 2016 Jun;22(6):541-5. doi: 10.1089/tmj.2015.0162. Epub 2015 Dec 22. PMID: 26693880.
[29] Hanna TN, Steenburg SD, Rosenkrantz AB, Pyatt RS Jr, Duszak R Jr, Friedberg EB. Emerging Challenges and Opportunities in the Evolution of Teleradiology. AJR Am J Roentgenol. 2020 Dec;215(6):1411-1416. doi: 10.2214/AJR.20.23007. Epub 2020 Oct 14. PMID: 33052736.

cross-state licensure, chief among them the Interstate Medical Licensure Compact of 2014[30]. This agreement aims to make it easier for medical practitioners to work across state lines–however, only 29 states are actually subject to this agreement. In fact, the largest states by population, including California, Florida, New York, and Texas, are not members of the Compact.

There is currently pending bipartisan legislation[31] that would compel states to join the Interstate Medical Licensure Compact or face penalty; however, as of the writing of this report, that legislation has not yet been passed.

2. Regulation

Regulation is another challenge facing teleradiologists. Individual states have certain mandates that make teleradiologists' jobs more difficult. For example, New York state[32] conducts quality control testing biweekly on diagnostic monitors (including those used in other states for teleradiology purposes), in addition to quarterly evaluations and annual testing by a licensed medical physicist. Naturally, complying with these regulations is more difficult for teleradiologists who live in rural areas (in fact, more rural states like Wisconsin have less strict regulations).

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[30] Interstate Medical Licensure Compact. (2014). A Faster Pathway to Physician Licensure. In *Interstate Medical Licensure Compact*. Retrieved from https://www.imlcc.org/a-faster-pathway-to-physician-licensure/

[31] Jercich, K. (2020, November 25). In *House bill would compel states to join the Interstate Medical Licensure Compact*. Retrieved from https://www.healthcareitnews.com/news/house-bill-would-compel-states-join-interstate-medical-licensure-compact

[32] Experity Health. (n.d.). NY Urgent Cares: Are You in Compliance with Quality Assurance Regulations for Primary Diagnostic Monitors?. In *Experity Health*. Retrieved from https://www.experityhealth.com/resources/primary-diagnostic-monitors/

Like licensing, regulation is ultimately a legislative issue. Obviously, rigorous regulation exists for a very good reason–to protect the health of patients–but, ironically, unnecessarily strict legislation may actually be impeding patients' access to quality care. Evidence-based regulation is needed, with standardization across geography. Given the muscle behind many teleradiology companies (including, among others, such companies as Google and General Electric), and the general bipartisan consensus about the desirable effects of teleradiology, lobbying efforts to Congress might be a compelling way to move the needle on legislation.

3. Systems Integration and Communication

Finally, collection of clinical information poses a challenge to the field of teleradiology. Teleradiologists must collect data and images from a melange of hospitals and clinics, all of which use different PACS and electronic medical record systems. These barriers to data sharing are perhaps the single largest impedance to the field of teleradiology. There must be a way to increase data-sharing capabilities without compromising the security of patient records.

There are a few compelling solutions to this problem. The first, and most obvious, is the creation of a centralized, nationwide electronic medical records system. This would vastly improve the portability of patient records, allowing for easy access to information unconstrained by geography[33]. This approach is not without precedent, either. After the US Department of Veterans Affairs adopted a national electronic health records system in 1999, the availability of needed records during clinical observation increased by 40%[34].

[33] Persaud N. (2019). A national electronic health record for primary care. *CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne*, *191*(2), E28–E29. https://doi.org/10.1503/cmaj.181647

[34] Perlin JB, Kolodner RM, Roswell RH. The Veterans Health Administration: quality, value, accountability, and information as transforming strategies for patient-centered care. Am J Manag Care. 2004 Nov;10(11 Pt 2):828-36. PMID: 15609736.

Another solution is improving PACS infrastructure[35]. This could include measures such as integration of multisource PACS, connection of PACS systems between different hospital systems, and the adoption of open source PACS. All of these solutions would increase the availability of medical images, greatly improving the access to teleradiology services.

B: Opportunities

Global Teleradiology

The best thing about the internet is that it has improved access to information not only around the country, but around the world. While teleradiology limited to the United States would lead to gains in efficiency and patient outcomes, expanding teleradiology technologies to the entire world would lead to tremendous cost savings (assuming that one could get past licensure and regulatory concerns. In the United States, the average radiologist earns, on average, $420,790[36]. In India, the average radiologist earns, on average, $24,887[37]. Using the arbitrage opportunity afforded by teleradiology, patients in high-cost healthcare systems, like the United States, could see huge cost reductions.

Dental Teleradiology

[35] Alhajeri, M., & Shah, S. (2019). Limitations in and Solutions for Improving the Functionality of Picture Archiving and Communication System: an Exploratory Study of PACS Professionals' Perspectives. *Journal of digital imaging*, *32*(1), 54–67. https://doi.org/10.1007/s10278-018-0127-2

[36] Radiologist Salary in the United States. (n.d.). In *Salary.com*. Retrieved from https://www.salary.com/research/salary/alternate/radiologist-salary

[37] Head of Radiology Salary. (n.d.). In *SalaryExpert.com*. Retrieved from https://www.salaryexpert.com/salary/job/head-of-radiology/india

While teleradiology for medical ailments is fairly commonplace, teleradiology for dental scans is far less so. According to GrandView Research, the global dental X-ray market was valued at $536.5 million in 2020, and is expected to expand at a CAGR of 18.6% from 2021-2028[38]. Capturing this market through teleradiology is a very strong prospect, as the value proposition of teleradiology is the same for dental X-rays as it is for traditional X-rays or MRIs. In fact, a majority of dentists surveyed by Simon et. al. indicated that they would be willing to conduct teleradiology on dental X-rays were the infrastructure available[39].

AI Teleradiology

The opportunities presented by this emerging technology are discussed in detail in Section 4.

Access-Expanding Technologies

The opportunities presented by this emerging technology are discussed in detail in Section 4.

[38] GrandView Research. (2021, January 21). Dental X-ray Market Size, Share & Trends Analysis Report By Product (Analog, Digital), By Type (Intraoral, Extraoral), By Application (Medical, Cosmetic Dentistry, Forensic), By Region, And Segment Fo. In *GrandView Research*. Retrieved from https://www.grandviewresearch.com/industry-analysis/dental-x-ray-market

[39] Simon L, Friedland B. Interstate Practice of Dental Teleradiology in the United States: The Effect of Licensing Requirements on Oral and Maxillofacial Radiologists' Practice Patterns. Telemed J E Health. 2016 Jun;22(6):541-5. doi: 10.1089/tmj.2015.0162. Epub 2015 Dec 22. PMID: 26693880.