

# Overview of Telepathology



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## KEYWORDS

- Telepathology • Digital imaging • Robotic • Static • Teleconsultation
- Telemicroscopy • Virtual microscopy • Whole-slide imaging

## OVERVIEW

Telepathology is the practice of pathology at a distance, transmitting macroscopic and/or microscopic images using telecommunication links for remote interpretations (telediagnosis), second opinions or consultations (teleconsultation), and/or for educational purposes.<sup>1–4</sup> The original material (eg, glass slide) is spatially separated from the remote consultant (telepathologist) who will interpret a representative image of the material. The digital or analog image is remotely viewed on a computer monitor or cell phone screen. Ubiquitous access to the Internet, or to other broadband telecommunications linkages, facilitates nearly global image sharing. As a result, telepathology has been used to aid a growing number of laboratories around the world to deliver pathology services by allowing them to easily connect with experts. Telepathology has even been used to enhance the efficiency of pathology services between hospitals less than a mile apart.<sup>5,6</sup> With increasing subspecialization in pathology, the use of telepathology to access subspecialists (eg, neuropathologists) has been extremely beneficial.<sup>7–12</sup> The practice of telepathology, however, is not only limited to diagnostic work but can be used in quality assurance (eg, rereview of cases), education, and research.<sup>9,11</sup>

The first recorded instance of “telepathology” occurred in the late 1960s, when a real-time “television microscopy” service was established between Massachusetts General Hospital (MGH) and Logan Airport Medical Station in Boston, Massachusetts.<sup>13</sup> Since then, there has been a proliferation of telepathology technology and services worldwide.<sup>14,15</sup> The number of “telepathology” citations indexed in MEDLINE has grown from the first citation listed in 1986 to 900 citations in 2015. The variety of telepathology systems developed and applications deployed continues to grow. To date, 12 distinct classes of telepathology systems have been described in the literature. These are listed in the Weinstein Telepathology System Classification, the primary modes of which are static imaging, dynamic imaging, and virtual slide

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telepathology.<sup>9</sup> Despite the low equipment start-up costs, static image telepathology was slowly replaced by dynamic methods in an attempt to improve diagnostic accuracy.<sup>16,17</sup> With dynamic telepathology, the telepathologist is more actively involved in glass slide field selection, typically by using robotic, remote-controlled microscopy.<sup>18–20</sup> Virtual slide telepathology is the most recently developed mode of telepathology. This technology is also referred to as whole-slide imaging (WSI) telepathology. WSI systems produce giant, high-resolution, digital images of entire glass slides (ie, digital slides).<sup>21</sup> With disruptive WSI technology, innovative telepathology services have emerged.<sup>12</sup>

There are many potential uses of telepathology. Telepathology has been applied in anatomic pathology (eg, remote frozen section diagnosis, telectytopology) and clinical pathology (eg, telehematology, telemicrobiology). Drawbacks to the widespread use of telepathology include cost, technology restrictions (eg, limited resolution, large image files), resistance from pathologists (eg, reluctance, skepticism, technophobia), lack of standards, and the potential threat of competition for pathology services. The development of standards for digital radiology imaging was critical to the success of teleradiology, and the same is likely to be true for telepathology. Standards for telepathology have begun to be developed, such as the recent guidelines set forth by the American Telemedicine Association.<sup>22</sup> The Canadian Association of Pathologists and Royal College of Pathologists also have published guidelines for telepathology.<sup>23,24</sup> Emerging legal and regulatory issues in telepathology also are being addressed, which will hopefully catalyze the practice of telepathology.<sup>25</sup>

## TELEHEALTH

Telepathology falls under the broader category of telehealth. According to the Office for the Advancement of Telehealth, telehealth is defined as the use of electronic information and telecommunications technologies to support “long-distance” clinical health care, patient and professional health-related education, public health, and health administration. Telemedicine, another branch of telehealth, describes the remote transfer of clinical information via electronic communications.<sup>3,26</sup> Technologies used in telemedicine include the Internet, videoconferencing, store-and-forward imaging, streaming media, and wireless communications. Telemedicine can be further subdivided by specialty (eg, telepathology, teleradiology, teledermatology, telesurgery, telepsychiatry). The field of telemedicine is broad, because it also includes telerounding (eg, e-ICU “rounding”), telemonitoring (eg, home arrhythmia monitoring), televisits, telehome care, and telemanagement of patients.<sup>27</sup> Currently, most telemedicine programs consist of a central medical hub with several rural spokes, so as to improve access to services in underserved areas. Telehealth initiatives are growing due to lower costs of technology, federal funds supporting such programs, and advancements in technology.<sup>28</sup> Although the various branches of telehealth present unique opportunities for both patients and clinicians, they also possess distinct operational, ethical, and legal issues.<sup>29</sup> As the field grows, more standards and telepractice guidelines will be needed.<sup>30</sup>

## HISTORICAL OVERVIEW

The history of telepathology has been long and eventful.<sup>15,16,31</sup> A list of several major milestones are provided in **Table 1**. The first telepathology event occurred in 1968, when black-and-white real-time television images of blood smears and urine specimens were sent from Logan Airport in Boston to the MGH for interpretation. In the 1990s, the value of telepathology for diagnosis was showcased by a landmark paper

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