SIIM 2017 Scientific Session
Posters & Demonstrations

Clinical Image Repositories to Conduct Quantitative Pediatric Research – Lessons Learned

Kirk E. Smith, University of Arkansas for Medical Sciences; Tracy S. Nolan; Fred W. Prior; Sergei Turovets; Linda J. Larson-Prior

Introduction

Imaging research relies on the acquisition and quantitative analysis of high quality data. An immense amount of imaging data is available in clinical databases and there is increasing interest in utilizing these data in both basic and clinical research [1]. A challenge in the use of such data is that, unlike databases developed under controlled experimental conditions, clinical data from hospital picture archive and communication systems (PACS) and electronic health record systems are acquired based on clinical need and intended for primarily visual analysis by medical professionals.

To develop accurate pediatric head models for use in high density electroencephalography (hdEEG) source imaging, we required computed tomography (CT) and magnetic resonance (MR) image data in the same child collected within a 6 month period. These data could not ethically be acquired prospectively [2], but could be obtained retrospectively by mining the clinical image repository at our institution.

Evaluation

Following an Internal Review Board approved protocol, CT and MR data were mined from the enterprise clinical repository of the BJC Health System in St. Louis [3]. The goal was to obtain head imaging data in pediatric patients (birth to 18 years of age) where no clinical pathology was indicated. We implemented a four level review to ensure that accepted data were of high quality. The levels consisted of (1) screening radiology reports, (2) an initial review of image data to eliminate obviously poor images, (3) importation of image data to image processing and visualization software followed by a more rigorous review of image quality, and (4) a final review based on problems encountered during automated image processing. Figure 1 illustrates the search workflow used in identification of useable data sets and assignment of these data to initial preprocessing pipelines.

Level 1 searches were performed using the RIS Search system which indexes all radiology reports that have been generated at the Barnes Jewish Hospital and Saint Louis Children's hospital [4]. The RIS Search query tool provides a search engine like interface and supports searches on free text radiology report records (Fig. 1A), returning report texts for identified patients based on search criteria defined by the user.

Figure 1

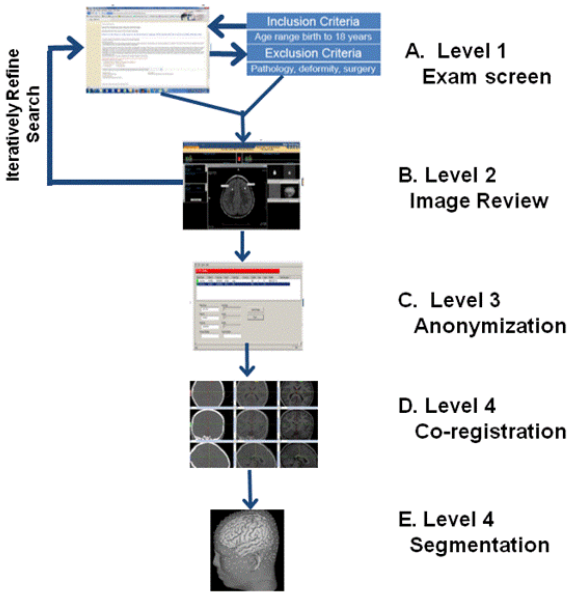

FIGURE 1: Review and retrieval of pediatric neuroimaging data from a clinical data repository. A four-tiered review of CT and MR data was implemented to identify clinical data suitable for quantitative image analysis.

Our search preparatory to research identified 174,000 possible cases, using a search string (MR+CT) across multiple sites and likely returned a large number of cases in which data were out of our current age range and/or from non-cranial imaging studies.

Further refinement to the search string was needed to eliminate multiple visits by the same child prior to and following surgical resections (CT+MR+brain+head-resection+CH) resulted in a total of 2,500 exam reports. All free-text radiology reports were then reviewed for inclusion of reports from both MR and CT scans. A total of 385 studies were identified and logged in the first level review (see Table 1).

Table 1

Table 1: Data Retrieval

Rejection Criteria	Level 1: Exam Report Search	Level 2: Image Archive Search	Level 3: Image Quality	Level 4: Coregistration
Data unavailable	n/a	24	n/a	n/a
Scan interval	250	45	8	13
Pathology	1,252	26	6	n/a
Technique	803	18	n/a	17
Resolution/FoV	n/a	29	29	20
Motion	n/a	27	23	n/a
Other	1,595	24	8	5

Data review at the second level depended upon visual inspection of imaging data. As noted in Table 1, the most common cause of exclusion at this level was due to an overlong interval between MR and CT scans. In a number of cases, imaging data referenced in level 1 clinical reports were not available in the Enterprise Image Archive. Another common reason for exclusion was identification of significant brain or skull pathology, or excessive head motion. The second level of review resulted in inclusion of 89% of identified data sets for subsequent review and processing.

Following our IRB protocol, data were de-identified, uploaded to a secure FTP site prior to the third level of review. In the third level of review, data were loaded into an image processing and visualization software system specific to the analyses undertaken at each processing site and examined for quality using three-dimensional tools. The level 3 image review was performed using 3D views for image quality assessments.

The fourth and final level of review evaluated those data that failed automated processing. Automated processing occurred at two separate locations, one focused on brain segmentation and classification and the other on skull morphometrics and co-registration of MR and CT data [5]. Thus, at this level, data were excluded primarily based on an inability to segment tissue types (gray matter, white matter, and cerebrospinal fluid layer) in brain and skull (scalp and skull). This final review resulted in inclusion of 63.6% of the data analyzed.

Discussion

A number of issues related to search criteria arose during level 1 review. Our initial search string included the term "normal", but the search engine based RIS Search query tool also returned results from "not normal". Similarly, the term 'head' was insufficient to return cranial information, including non-cranial results such as 'head of the femur'. An additional problem with the use of the term 'normal' in clinical reports occurred when 'normal' referred to a follow-up study in an individual who initially presented with significant neural deformity or had undergone surgical resection. The largest number of data exclusions resulted from such failures in the interpretation of search criteria, where 11,000 cases were identified when only 385 cases actually met inclusion criteria (3.5% of initially identified cases).

Second level review highlighted an important difference between data collected for clinical use and that collected under controlled experimental conditions. No consistent field of view is used in clinical scans, which are optimized by the radiology technician for clinical evaluation and often zoomed in on particular aspects of potentially injured or pathological anatomy (e.g. sellae, orbits). Thus, it was not uncommon to find that MR data did not provide full head coverage. In addition, as many clinical scans are done under sub-optimal conditions in young children, head motion is a significant confound even when efforts have been made to stabilize the head and reduce the ability to move.

Implementation of a data de-identification step is required to ensure that no protected health information is passed between sites over the internet.

Conclusion

Clinical data repositories offer a means to incorporate difficult to obtain retrospective imaging data for quantitative scientific research, but bring unique challenges with them. Despite the fact that large, tertiary care medical centers collect immense amounts of imaging data per year, the amount of data available in any specific area of potential scientific import may be relatively small. As we have shown, even when apparently large amounts of data are available, only a small percentage of that data will be suitable for quantitative analysis.

Large-scale use of retrospectively collected clinical datasets offers unique informatics challenges as well, including the need for full patient de-identification of both image data and any associated meta-data.

We had predicted a 5% acceptance rate of data appropriate for constructing pediatric head models, based on initial sampling. Upon review completion, we found that .04% of the initially identified potential subjects were useful for analysis. These results suggest that while clinical image repositories house large volumes of data, these data may not be optimal for quantitative analysis and the data selection process is complex.

References

1. M. A. Levy, J. B. Freymann, J. S. Kirby, A. Fedorov, F. M. Fennessy, S. A. Eschrich, A. E. Berglund, D. A. Fenstermacher, Y. Tan, and X. Guo, "Informatics methods to enable sharing of quantitative imaging research data," Magnetic Resonance Imaging, 2012.
2. D. Brenner, "Minimising medically unwarranted computed tomography scans," Annals of the ICRP, 2012.
3. K. W. Clark, D. L. Melson, S. M. Moore, G. James Blaine, R. A. Moulton, W. K. Clayton, C. S. Peterson, and B. A. Vendt, "Tools for managing image flow in the modality to clinical-image-review chain," Journal of Digital Imaging, vol. 16, pp. \ 310-317, 2003.
4. J. Erinjeri, D. Picus, F. Prior, D. Rubin, and P. Koppel, "Development of a Google-Based Search Engine for Data Mining Radiology Reports," Journal of Digital Imaging, vol. 22, pp. 348-356, 2009.
5. K. E. Smith, B. R. Whiting, G. G. Reiker, P. K. Commean, D. R. Sinacore, and F. W. Prior, "Assessment of technical and biological parameters of volumetric quantitative computed tomography of the foot: a phantom study," Osteoporosis International, vol. 23, pp. 1977-1985, 2012.

Keywords

clinical repository, quantitative research, pediatric head models