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DOSE MANAGEMENT SPECIAL REPORT

COMPUTER-DETERMINED INTERPRETATION OF INTRACRANIAL ABNORMALITIES

WHERE ARE WE NOW IN THE ALGORITHM REVOLUTION?

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The past forty years has been a period of unprecedented and sustained advances in radiology with consecutive innovations expanding our specialty's reach and its diagnostic and therapeutic prowess. Technology has been the midwife of our gains as more and more incisive capabilities have come within our purview. But now we must reckon with the realisation that not every 'improvement' will be placed on our parochial agenda. Some may indeed threaten our primacy even as they effectively improve patient care. The genie has come out of the bottle, so to speak, eager to be deployed insistently and decisively. One instance in which the threshold has been trodden, making the challenge imminent and the disruption clearly evident, is the autonomous application of the computer for the definitive diagnosis of conditions affecting the brain and its coverings.

The integration of computers into our practice over the past twenty-five years or so has been a felicitous development. They have been incorporated into cross-sectional imaging devices, have made possible the telecommunication of pictures as well as words, and have supported the voice generation of reports. The virtues of these accretions to our clinical acumen and our delivery of expertise are undeniable. More controversial has been the conjunction of histologic references with pictographic patterns as evaluated by computers in mammographic analysis. It is this application to which we have affixed the term computer-assisted diagnosis, or CAD.

It is ironic that the first widespread linkage of morphology to cell type with computers has taken place in the context of the diagnosis of breast malignancy. The mammographic image is characterised by a spectrum of shades of white, black and grey, making it difficult to distinguish abnormality from normal, especially in dense breasts. Faint calcifications are also discriminating, but here too some distinctions are not clear cut. Computer assistance, its adherents maintain, helps bridge the gap between two realms of spatial display—macroscopic patterns and microscopic cellular identity. The accuracy of CAD remains a subject for continuing discussion. The problem it addresses is unique—as providing a pathway for future refinements it is not a dead end but rather a cul-de-sac. We must look elsewhere to evaluate computerisation's potential for furthering its integration into imaging interpretation.

And that may now be happening. Recent augmentations in computerisation power in the assessment of Big Data have focused computer-directed analysis in novel ways. The claim being made now of CT and MR evaluations of intra and extra axial lesions is that an unaided computer investigation can make a diagnostic determination, not merely assist in one. In the breast, computers are meant to link macroscopy with microscopy. In the brain it is morphology alone for what they can now be tasked.

The brain is a rigidly circumscribed, symmetrical organ with clearly delineated parenchymal conformations and intervening and surrounding liquid spaces housed in an unyielding radiopaque shell. It is ideal for the recognition of expansile, constrictive and eccentric abnormalities by experienced interpreters. But now sophisticated computer algorithms, informed by comprehensive databases of the brain, generated in various conditions and at various ages, potentially offer a substitute means of pattern comprehension at least equal to the interpretation of a radiologist.

> "COMPUTER ALGORITHMS... POTENTIALLY OFFER A SUBSTITUTE MEANS OF PATTERN COMPREHENSION AT LEAST EQUAL TO THE INTERPRETATION OF A RADIOLOGIST"

That is the prospect. What to date is the evidence? A first report from Japan in 2005, published in *Radiology*, assessed computer 'assistance' for the diagnosis of intracranial aneurysms by MR (Hirai et al. 2005). Only saccular or fusiform aneurysms alone were assessed. CAD was judged better than radiologist interpretation but about equal with that of neuroradiologists who did not avail themselves of the computer program. In 2010 a small series of patients with either intracranial, subdural, or epidural blood collections revealed equal results by computer alone and by the evaluation of a neurosurgeon (Liao et al. 2010). A retrospective review of a computer algorithm to detect midline shift appeared in another article in 2010 (Xiao et al.). In 53 patients, the results had a sensitivity of 94% and a specificity of 100%.

A more recent report regarding computer detection of stroke lesions at CT showed that CAD proved useful for diagnosis of both haemorrhagic and ischaemic strokes, and better for the detection of haemorrhagic lesions (Gillebert et al. 2014). The authors focused on old atrophic brains. Most recently, in 2015, computer diagnosis was assessed for tissue characterisation of brain tumours by MR (Arakeri and Reddy 2015). This sophisticated program considered shape, texture, wavelet and boundary characteristics. The computerised interpretations equalled that of a neuroradiologist and exceeded the evaluations of two less-experienced radiologists (Arakeri and Reddy 2015).

These reports together reflect the increasing capability of computer determination. We emphasise here the thrust of these studies was for computer determination not assistance. Clearly they betoken a compelling alternative to conventional interpretation by qualified specialists. The payoff could be great for those who can demonstrate that the technique could be made available as a stand-alone exercise.

Furthermore, public perception may also play a role in the ultimate allocation of proprietorship of imaging studies in which computer determination will compete with diagnoses rendered by humans. The musings of opinion makers in the general population are often influential in ultimately directing both the choice of studies and the choice of caregivers responsible for the studies so chosen. A seemingly gratuitous comment in a recent Op-Ed column in the *New York Times* by the noted geopolitical pundit Thomas L. Friedman is germane (Friedman 2015). In an essay about the global agenda facing a new president, he stated: "Robots are milking cows and IBM's Watson computer can beat you at Jeopardy! [an American quiz show] and your doctor at radiology" (Friedman 2015). Or to paraphrase, it will beat your radiologist at diagnosis. So public audiences have been brought into the issue by this comment. Will they soon insist on a computer-determined report as a standard the 'fallible' radiologist may not be able to meet? That sounds perverse perhaps, but once the matter becomes a topic for lay discussion it cannot be ignored.

Moreover, it is likely that existing computer-determined algorithms will improve. A recent announcement by IBM about Watson indicates the company's interest in applying it to imaging (IBM 2015). So where will that situate radiology? For many CT and MR examinations of the brain, computer determination will be situated initially within radiology's domain. But once it is realised that the computer is doing the diagnostic work and the radiologist is now the manager of the device, and not the interpreting clinician, other physicians might seek to take the business away from us. In the United States, jurisdictional boundaries demarcating specialists' responsibilities are permeable. Neurologists and neurosurgeons could soon realise that the radiologist's interpretation may then become superfluous for routine cross-sectional imaging analysis of the brain. As long as procedure content and volume are directly related to income, they will attract interest from those physicians who regard themselves as conversant if not expert with the technique. For example, interventional neuroradiology, once the province of radiologists, primarily has now become populated in recent training programme classes by neurologists and neurosurgeons, who consider themselves at least as capable as radiologists to meet the subspecialty's challenges.

Hence we must acknowledge and so confront the great changes impinging upon us by the strident march of technology, no longer in step with us, but quite possibly ahead of us, determining the path clinical diagnosis will pursue. Will we stand aside or follow, or find another way to demonstrate enduring value? ■

Key Points

- ✓ Computers have benefited radiology over the last 25 years, including cross-sectional imaging, telecommunication and reporting.
- ✓ Computer-assisted diagnosis has been more controversial as to benefits and accuracy.
- ✓ Computers can now provide analysis of brain morphology equal to a neuroradiologist.
- ✓ Radiologists need to face the possibility of computer-determined diagnosis, and patients may yet prefer it.

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