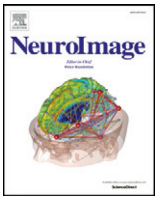
NeuroImage 139 (2016) 149–156

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/ynimg



The 100 most-cited articles in neuroimaging: A bibliometric analysis

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ARTICLE INFO

Article history:
Received 3 April 2016
Revised 16 June 2016
Accepted 17 June 2016
Available online 18 June 2016

Keywords:
Bibliometric analysis
Citation
Citation classics
Neuroimaging

ABSTRACT

The purpose of our study was to identify and characterize the 100 most-cited articles in neuroimaging. Based on the database of Journal Citation Reports, we selected 669 journals that were considered as potential outlets for neuroimaging articles. The Web of Science search tools were used to identify the 100 most-cited articles relevant to neuroimaging within the selected journals. The following information was recorded for each article: publication year, journal, category and impact factor of journal, number of citations, number of annual citations, authorship, department, institution, country, article type, imaging technique used, and topic. The 100 most-cited articles in neuroimaging were published between 1980 and 2012, with 1995–2004 producing 69 articles. Citations ranged from 4384 to 673 and annual citations ranged from 313.1 to 24.9. The majority of articles were published in radiology/imaging journals ($n = 75$), originated in the United States ($n = 58$), were original articles ($n = 63$), used MRI as imaging modality ($n = 85$), and dealt with imaging technique ($n = 45$). The Oxford Centre for Functional Magnetic Resonance Imaging of the Brain at John Radcliffe Hospital ($n = 10$) was the leading institutions and Karl J. Friston ($n = 11$) was the most prolific author. Our study presents a detailed list and an analysis of the 100 most-cited articles in the field of neuroimaging, which provides an insight into historical developments and allows for recognition of the important advances in this field.

Introduction

Neuroimaging is a branch of medical imaging that focuses on the central nervous system. The field of neuroimaging has rapidly grown and evolved through advancements of imaging technologies over the past decades (Hoeffner et al., 2012). This development could be indicated by a large number of articles published in the scientific journals.

A citation is the acknowledgement that one scientific article (the citing article) uses another (the cited article) as a reference. The number of citations is not only an indicator of the impact of an article on the scientific community but also form the basis of journal impact factor (IF) generation (Moed, 2009; Eyre-Walker and Stoletzki, 2013). Therefore, reviewing the most-cited articles (so-called "citation classics") can provide interesting information about scientific progress and research trends in a specific field of discipline.

A number of studies have reported the most-cited articles in various clinical disciplines, such as general surgery (Paladugu et al., 2002), anesthesiology (Baltussen and Kindler, 2004), neurosurgery (Ponce and Lozano, 2010), obstetrics and gynecology (Brandt et al., 2010), orthopedics (Kelly et al., 2010), and rehabilitation (Shadgan et al., 2010). As the first study in the field of radiology, Chew listed the 50 most frequently cited papers published in the *American Journal of Roentgenology* in 1988 (Chew, 1988). Recently, several authors published bibliometric analyses of the 100 most-cited articles in the field of radiology (Yoon et al., 2013; Brinjikji et al., 2013; Pagni et al., 2014) or radiological subspecialties (Crockett et al., 2015; Dolan et al., 2015). To our knowledge, however there has been no bibliometric analysis of the most-cited articles in the field of neuroimaging.

The purpose of present study was to identify and analyze the 100 most-cited articles in the field of neuroimaging.

Materials and methods

Our study was a bibliometric analysis that did not involve human subjects and was exempted from the need for an institutional review board approval.

Two reviewers (H.J.K. and E.S.K., board-certified neuroradiologists with 5 and 10 years of experience, respectively) independently conducted journal selection, article identification, and analyses of articles. Any disagreements between reviewers were resolved by a third reviewer (D.Y.Y., a board-certified neuroradiologist with 20 years' experience).

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http://dx.doi.org/10.1016/j.neuroimage.2016.06.029
1053-8119/

Table 1
The 100 most-cited neuroimaging articles ranked in order of the number of citations received.

Ranking	Article	No. of citations	No. of citations/year (ranking)
1	Tzourio-Mazoyer N, Landeau B, Papathanassiou D, Crivello F, Etard O, Delcroix N, Mazoyer B, Joliot M. Automated anatomical labeling of activations in SPM using a macroscopic anatomical parcellation of the MNI MRI single-subject brain. *Neuroimage* 2002;15(1):273–89.	4384	313.1 (1)
2	Ashburner J, Friston KJ. Voxel-based morphometry—the methods. *Neuroimage* 2000;11(6 Pt 1):805–21.	3973	248.3 (2)
3	Smith SM. Fast robust automated brain extraction. *Hum Brain Mapp* 2002;17(3):143–55.	3201	243.1 (4)
4	Biswal B, Yetkin FZ, Haughton VM, Hyde JS. Functional connectivity in the motor cortex of resting human brain using echo-planar MRI. *Magn Reson Med* 1995;34(4):537–41.	2928	144.6 (16)
5	Smith SM, Jenkinson M, Woolrich MW, Beckmann CF, Behrens TE, Johansen-Berg H, Bannister PR, De Luca M, Drobnjak I, Flitney DE, Niazy RK, Saunders J, Vickers J, Zhang Y, De Stefano N, Brady JM, Matthews PM. Advances in functional and structural MR image analysis and implementation as FSL. *Neuroimage* 2004;23 Suppl 1:S208–19.	2763	243.8 (3)
6	Jenkinson M, Bannister P, Brady M, Smith S. Improved optimization for the robust and accurate linear registration and motion correction of brain images. *Neuroimage* 2002;17(2):825–41.	2627	198.3 (8)
7	Genovese CR, Lazar NA, Nichols T. Thresholding of statistical maps in functional neuroimaging using the false discovery rate. *Neuroimage* 2002;15(4):870–8.	2623	190.8 (9)
8	Dale AM, Fischl B, Sereno MI. Cortical surface-based analysis. I. Segmentation and surface reconstruction. *Neuroimage* 1999;9(2):179–94.	2543	150.3 (14)
9	Good CD, Johnsrude IS, Ashburner J, Henson RN, Friston KJ, Frackowiak RS. A voxel-based morphometric study of ageing in 465 normal adult human brains. *Neuroimage* 2001;14(1 Pt 1):21–36.	2481	171.1 (11)
10	Maldjian JA, Laurienti PJ, Kraft RA, Burdette JH. An automated method for neuroanatomic and cytoarchitectonic atlas-based interrogation of fMRI data sets. *Neuroimage* 2003;19(3):1233–9.	2336	186.9 (10)
11	Jenkinson M, Smith S. A global optimisation method for robust affine registration of brain images. *Med Image Anal* 2001;5(2):143–56.	2192	151.2 (13)
12	Giedd JN, Blumenthal J, Jeffries NO, Castellanos FX, Liu H, Zijdenbos A, Paus T, Evans AC, Rapoport JL. Brain development during childhood and adolescence: a longitudinal MRI study. *Nat Neurosci* 1999;2(10):861–3.	2141	131.8 (21)
13	Cabeza R, Nyberg L. Imaging cognition II: An empirical review of 275 PET and fMRI studies. *J Cogn Neurosci* 2000;12(1):1–47.	2131	133.2 (20)
14	Fischl B, Sereno MI, Dale AM. Cortical surface-based analysis. II: Inflation, flattening, and a surface-based coordinate system. *Neuroimage* 1999;9(2):195–207.	2061	121.8 (23)
15	Fox MD, Raichle ME. Spontaneous fluctuations in brain activity observed with functional magnetic resonance imaging. *Nat Rev Neurosci* 2007;8(9):700–11.	2004	240.5 (5)
16	Zhang Y, Brady M, Smith S. Segmentation of brain MR images through a hidden Markov random field model and the expectation-maximization algorithm. *IEEE Trans Med Imaging* 2001;20(1):45–57.	1939	129.3 (22)
17	Klunk WE, Engler H, Nordberg A, Wang Y, Blomqvist G, Holt DP, Bergström M, Savitcheva I, Huang GF, Estrada S, Ausén B, Debnath ML, Barletta J, Price JC, Sandell J, Lopresti BJ, Wall A, Koivisto P, Antoni G, Mathis CA, Långström B. Imaging brain amyloid in Alzheimer's disease with Pittsburgh Compound-B. *Ann Neurol* 2004;55(3):306–19.	1938	163.8 (12)
18[a]	Nichols TE, Holmes AP. Nonparametric permutation tests for functional neuroimaging: a primer with examples. *Hum Brain Mapp* 2002;15(1):1–25.	1924	137.4 (18)
18[a]	Smith SM, Jenkinson M, Johansen-Berg H, Rueckert D, Nichols TE, Mackay CE, Watkins KE, Ciccarelli O, Cader MZ, Matthews PM, Behrens TE. Tract-based spatial statistics: voxelwise analysis of multi-subject diffusion data. *Neuroimage* 2006;31(4):1487–505.	1924	202.5 (7)
20	Aaslid R, Markwalder TM, Nornes H. Noninvasive transcranial Doppler ultrasound recording of flow velocity in basal cerebral arteries. *J Neurosurg* 1982;57(6):769–74.	1835	55.5 (63)
21	Beaulieu C. The basis of anisotropic water diffusion in the nervous system - a technical review. *NMR Biomed* 2002;15(7–8):435–55.	1802	137.3 (19)
22	Mori S, Crain BJ, Chacko VP, van Zijl PC. Three-dimensional tracking of axonal projections in the brain by magnetic resonance imaging. *Ann Neurol* 1999;45(2):265–9.	1797	106.2 (29)
23	Lancaster JL, Woldorff MG, Parsons LM, Liotti M, Freitas CS, Rainey L, Kochunov PV, Nickerson D, Mikiten SA, Fox PT. Automated Talairach atlas labels for functional brain mapping. *Hum Brain Mapp* 2000;10(3):120–31.	1786	111.6 (26)
24	Provencher SW. Estimation of metabolite concentrations from localized in vivo proton NMR spectra. *Magn Reson Med* 1993;30(6):672–9.	1752	79.3 (38)
25	Fisher CM, Kistler JP, Davis JM. Relation of cerebral vasospasm to subarachnoid hemorrhage visualized by computerized tomographic scanning. *Neurosurgery* 1980;6(1):1–9.	1746	48.5 (74)
26	Le Bihan D, Breton E, Lallemand D, Grenier P, Cabanis E, Laval-Jeantet M. MR imaging of intravoxel incoherent motions: application to diffusion and perfusion in neurologic disorders. *Radiology* 1986;161(2):401–7.	1666	57.1 (61)
27	Worsley KJ, Marrett S, Neelin P, Vandal AC, Friston KJ, Evans AC. A unified statistical approach for determining significant signals in images of cerebral activation. *Hum Brain Mapp* 1996;4(1):58–73.	1665	82.9 (35)
28	Phan KL, Wager T, Taylor SF, Liberzon I. Functional neuroanatomy of emotion: a meta-analysis of emotion activation studies in PET and fMRI. *Neuroimage* 2002;16(2):331–48.	1637	116.9 (25)
29	Pierpaoli C, Jezzard P, Basser PJ, Barnett A, Di Chiro G. Diffusion tensor MR imaging of the human brain. *Radiology* 1996;201(3):637–48.	1507	79.0 (39)
30	Eickhoff SB, Stephan KE, Mohlberg H, Grefkes C, Fink GR, Amunts K, Zilles K. A new SPM toolbox for combining probabilistic cytoarchitectonic maps and functional imaging data. *Neuroimage* 2005;25(4):1325–35.	1486	139.3 (17)
31	Friston KJ, Harrison L, Penny W. Dynamic causal modelling. *Neuroimage* 2003;19(4):1273–302.	1466	118.1 (24)
32	Basser PJ, Pajevic S, Pierpaoli C, Duda J, Aldroubi A. In vivo fiber tractography using DT-MRI data. *Magn Reson Med* 2000;44(4):625–32.	1457	95.5 (30)
33	Friston KJ, Holmes AP, Poline JB, Grasby PJ, Williams SC, Frackowiak RS, Turner R. Analysis of fMRI time-series revisited. *Neuroimage* 1995;2(1):45–53.	1450	69.6 (48)
34	Desikan RS, Ségonne F, Fischl B, Quinn BT, Dickerson BC, Blacker D, Buckner RL, Dale AM, Maguire RP, Hyman BT, Albert MS, Killiany RJ. An automated labeling system for subdividing the human cerebral cortex on MRI scans into gyral based regions of interest. *Neuroimage* 2006;31(3):968–80.	1409	148.3 (15)
35	Boynton GM, Engel SA, Glover GH, Heeger DJ. Linear systems analysis of functional magnetic resonance imaging in human V1. *J Neurosci* 1996;16(13):4207–21.	1392	71.4 (45)
36	Worsley KJ, Friston KJ. Analysis of fMRI time-series revisited—again. *Neuroimage* 1995;2(3):173–81.	1361	66.9 (50)
37	Bandettini PA, Jesmanowicz A, Wong EC, Hyde JS. Processing strategies for time-course data sets in functional MRI of the human brain. *Magn Reson Med* 1993;30(2):161–73.	1311	58.5 (59)
38	Friston, KJ; Buechel, C; Fink, GR; Morris, J; Rolls, E; Dolan, RJ. Psychophysiological and modulatory interactions in neuroimaging. *Neuroimage*1997;6(3):218–29.	1305	71.5 (44)
39	Ogawa S, Lee TM, Nayak AS, Glynn P. Oxygenation-sensitive contrast in magnetic resonance image of rodent brain at high magnetic fields. *Magn Reson Med* 1990;14(1):68–78.	1298	50.4 (70)
40	Le Bihan D, Mangin JF, Poupon C, Clark CA, Pappata S, Molko N, Chabriat H. Diffusion tensor imaging: concepts and applications. *J Magn Reson Imaging* 2001;13(4):534–46.	1232	83.5 (34)

Table 1 (*continued*)

Ranking	Article	No. of citations	No. of citations/year (ranking)
41	Moseley ME, Cohen Y, Mintorovitch J, Chileuitt L, Shimizu H, Kucharczyk J, Wendland MF, Weinstein PR. Early detection of regional cerebral ischemia in cats: comparison of diffusion- and T2-weighted MRI and spectroscopy. *Magn Reson Med* 1990;14(2):330–46.	1217	47.4 (78)
42	Friston KJ, Fletcher P, Josephs O, Holmes A, Rugg MD, Turner R. Event-related fMRI: characterizing differential responses. *Neuroimage* 1998;7(1):30–40.	1208	67.1 (49)
43	Ashburner J, Friston KJ. Nonlinear spatial normalization using basis functions. *Hum Brain Mapp* 1999;7(4):254–66.	1169	70.5 (46)
44	Bandettini PA, Wong EC, Hinks RS, Tikofsky RS, Hyde JS. Time course EPI of human brain function during task activation. *Magn Reson Med* 1992;25(2):390–7.	1161	49.2 (72)
45	Fischl B, Sereno MI, Tootell RB, Dale AM. High-resolution intersubject averaging and a coordinate system for the cortical surface. *Hum Brain Mapp* 1999;8(4):272–84.	1139	70.5 (47)
46	Woolrich MW, Ripley BD, Brady M, Smith SM. Temporal autocorrelation in univariate linear modeling of FMRI data. *Neuroimage* 2001;14(6):1370–86.	1073	76.2 (42)
47	Song SK, Sun. SW, Ramsbottom MJ, Chang C, Russell J, Cross AH. Dysmyelination revealed through MRI as increased radial (but unchanged axial) diffusion of water. *Neuroimage* 2002;17(3):1429–36.	1064	80.8 (37)
48	McKeown MJ, Makeig S, Brown GG, Jung TP, Kindermann SS, Bell AJ, Sejnowski TJ. Analysis of fMRI data by blind separation into independent spatial components. *Hum Brain Mapp* 1998;6(3):160–88.	1049	61.4 (55)
49	Fazekas F, Chawluk JB, Alavi A, Hurtig HI, Zimmerman RA. MR signal abnormalities at 1.5 T in Alzheimer's dementia and normal aging. *AJR Am J Roentgenol* 1987;149(2):351–6.	1047	36.8 (92)
50	Yushkevich PA, Piven J, Hazlett HC, Smith RG, Ho S, Gee JC, Gerig G. User-guided 3D active contour segmentation of anatomical structures: significantly improved efficiency and reliability. *Neuroimage* 2006;31(3):1116–28.	1043	109.8 (27)
51	Mori S, van Zijl PC. Fiber tracking: principles and strategies — a technical review. *NMR Biomed* 2002;15(7–8):468–80.	1023	77.9 (40)
52	Lachaux JP, Rodriguez E, Martinerie J, Varela FJ. Measuring phase synchrony in brain signals. *Hum Brain Mapp* 1999;8(4):194–208.	1006	62.2 (54)
53	Braver TS, Cohen JD, Nystrom LE, Jonides J, Smith EE, Noll DC. A parametric study of prefrontal cortex involvement in human working memory. *Neuroimage* 1997;5(1):49–62.	1002	52.7 (67)
54	Behrens TE, Berg HJ, Jbabdi S, Rushworth MF, Woolrich MW. Probabilistic diffusion tractography with multiple fibre orientations: What can we gain? *Neuroimage* 2007;34(1):144–55.	976	108.4 (28)
55	Wakana S, Jiang H, Nagae-Poetscher LM, van Zijl PC, Mori S. Fiber tract-based atlas of human white matter anatomy. *Radiology* 2004;230(1):77–87.	971	80.9 (36)
56	Behrens TE, Johansen-Berg H, Woolrich MW, Smith SM, Wheeler-Kingshott CA, Boulby PA, Barker GJ, Sillery EL, Sheehan K, Ciccarelli O, Thompson AJ, Brady JM, Matthews PM. Non-invasive mapping of connections between human thalamus and cortex using diffusion imaging. *Nat Neurosci* 2003;6(7):750–7.	948	75.8 (43)
57	Ostergaard L, Weisskoff RM, Chesler DA, Gyldensted C, Rosen BR. High resolution measurement of cerebral blood flow using intravascular tracer bolus passages. Part I: Mathematical approach and statistical analysis. *Magn Reson Med* 1996;36(5):715–25.	939	49.0 (73)
58	Tootell RB, Reppas JB, Kwong KK, Malach R, Born RT, Brady TJ, Rosen BR, Belliveau JW. Functional analysis of human MT and related visual cortical areas using magnetic resonance imaging. *J Neurosci* 1995;15(4):3215–30.	934	45.0 (81)
59	Dale AM, Sereno MI. Improved Localizadon of Cortical Activity by Combining EEG and MEG with MRI Cortical Surface Reconstruction: A Linear Approach. *J Cogn Neurosci* 1993;5(2):162–76.	927	40.5 (86)
60[a]	Collins DL, Zijdenbos AP, Kollokian V, Sled JG, Kabani NJ, Holmes CJ, Evans AC. Design and construction of a realistic digital brain phantom. *IEEE Trans Med Imaging* 1998;17(3):463–8.	920	52.3 (68)
60[a]	Watson JD, Myers R, Frackowiak RS, Hajnal JV, Woods RP, Mazziotta JC, Shipp S, Zeki S. Area V5 of the human brain: evidence from a combined study using positron emission tomography and magnetic resonance imaging. *Cereb Cortex* 1993;3(2):79–94.	920	40.4 (87)
62	Shenton ME, Kikinis R, Jolesz FA, Pollak SD, LeMay M, Wible CG, Hokama H, Martin J, Metcalf D, Coleman M, McCarley RW. Abnormalities of the left temporal lobe and thought disorder in schizophrenia. A quantitative magnetic resonance imaging study. *N Engl J Med* 1992;327(9):604–12.	917	39.2 (89)
63	Owen AM, McMillan KM, Laird AR, Bullmore E. N-back working memory paradigm: a meta-analysis of normative functional neuroimaging studies. *Hum Brain Mapp* 2005;25(1):46–59.	908	85.1 (33)
64	Poldrack RA, Wagner AD, Prull MW, Desmond JE, Glover GH, Gabrieli JD. Functional specialization for semantic and phonological processing in the left inferior prefrontal cortex. *Neuroimage* 1999;10(1):15–35.	885	53.6 (65)
65	Dale AM. Optimal experimental design for event-related fMRI. *Hum Brain Mapp* 1999;8(2–3):109–14.	874	53.5 (66)
66	Ochsner KN, Ray RD, Cooper JC, Robertson ER, Chopra S, Gabrieli JD, Gross JJ. For better or for worse: neural systems supporting the cognitive down- and up-regulation of negative emotion. *Neuroimage* 2004;23(2):483–99.	870	77.3 (41)
67	Fletcher PC, Henson RN. Frontal lobes and human memory: insights from functional neuroimaging. *Brain* 2001;124(Pt 5):849–81.	869	59.3 (58)
68	Power JD, Barnes KA, Snyder AZ, Schlaggar BL, Petersen SE. Spurious but systematic correlations in functional connectivity MRI networks arise from subject motion. *Neuroimage* 2012;59(3):2142–54.	857	218.8 (6)
69	Northoff G, Heinzel A, de Greck M, Bermpohl F, Dobrowolny H, Panksepp J. Self-referential processing in our brain—a meta-analysis of imaging studies on the self. *Neuroimage* 2006;31(1):440–57.	849	87.8 (32)
70	Calhoun VD, Adali T, Pearlson GD, Pekar JJ. A method for making group inferences from functional MRI data using independent component analysis. *Hum Brain Mapp* 2001;14(3):140–51.	848	59.9 (56)
71	Longstreth WT Jr., Manolio TA, Arnold A, Burke GL, Bryan N, Jungreis CA, Enright PL, O'Leary D, Fried L. Clinical correlates of white matter findings on cranial magnetic resonance imaging of 3301 elderly people. The Cardiovascular Health Study. *Stroke* 1996;27(8):1274–82.	847	43.6 (82)
72	Buxton RB, Wong EC, Frank LR. Dynamics of blood flow and oxygenation changes during brain activation: the balloon model. *Magn Reson Med* 1998;39(6):855–64.	843	47.9 (76)
73	Spatial registration and normalization of images Karl. J. Friston, J. Ashburner, C. D. Frith, J.-B. Poline, J. D. Heather, R. S. J. Frackowiak Friston KJ, Ashburner J, Frith CD, Poline JB, Heather JD, Frackowiak RSJ. Spatial registration and normalization of images. *Hum Brain Mapp* 1995;3(3):165–89.	839	40.3 (88)
74	Pfefferbaum A, Mathalon DH, Sullivan EV, Rawles JM, Zipursky RB, Lim KO. A quantitative magnetic resonance imaging study of changes in brain morphology from infancy to late adulthood. *Arch Neurol* 1994;51(9):874–87.	832	39.0 (90)
75	Binder JR, Frost JA, Hammeke TA, Cox RW, Rao SM, Prieto T. Human brain language areas identified by functional magnetic resonance imaging. *J Neurosci* 1997;17(1):353–62.	796	41.9 (84)
76	Cabeza R, Anderson ND, Locantore JK, McIntosh AR. Aging gracefully: compensatory brain activity in high-performing older adults. *Neuroimage* 2002;17(3):1394–402.	784	59.5 (57)
77	Raichle ME, Snyder AZ. A default mode of brain function: a brief history of an evolving idea. *Neuroimage* 2007;37(4):1083–90.	783	94.9 (31)

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Table 1 (*continued*)

Ranking	Article	No. of citations	No. of citations/year (ranking)
78	Saxe R, Kanwisher N. People thinking about thinking people. The role of the temporo-parietal junction in "theory of mind". *Neuroimage* 2003;19(4):1835–42.	779	62.7 (53)
79	Tofts PS, Kermode AG. Measurement of the blood-brain barrier permeability and leakage space using dynamic MR imaging. 1. Fundamental concepts. *Magn Reson Med* 1991;17(2):357–67.	776	31.1 (96)
80[a]	Song SK, Sun. SW, Ju WK, Lin SJ, Cross AH, Neufeld AH. Diffusion tensor imaging detects and differentiates axon and myelin degeneration in mouse optic nerve after retinal ischemia. *Neuroimage* 2003;20(3):1714–22.	774	63.6 (52)
80[a]	Warach S, Gaa J, Siewert B, Wielopolski P, Edelman RR. Acute human stroke studied by whole brain echo planar diffusion-weighted magnetic resonance imaging. *Ann Neurol* 1995;37(2):231–41.	774	37.0 (91)
82	Smith SM, Zhang Y, Jenkinson M, Chen J, Matthews PM, Federico A, De Stefano N. Accurate, robust, and automated longitudinal and cross-sectional brain change analysis. *Neuroimage* 2002;17(1):479–89.	771	57.8 (60)
83	Barkhof F, Filippi M, Miller DH, Scheltens P, Campi A, Polman CH, Comi G, Adèr HJ, Losseff N, Valk J. Comparison of MRI criteria at first presentation to predict conversion to clinically definite multiple sclerosis. *Brain* 1997;120(Pt 11):2059–69.	767	42.2 (83)
84	Bookheimer S. Functional MRI of language: new approaches to understanding the cortical organization of semantic processing. *Annu Rev Neurosci* 2002;25:151–88.	762	55.1 (64)
85	Gomori JM, Grossman RI, Goldberg HI, Zimmerman RA, Bilaniuk LT. Intracranial hematomas: imaging by high-field MR. *Radiology* 1985;157(1):87–93.	753	24.9 (100)
86	Mazziotta JC, Toga AW, Evans A, Fox P, Lancaster J. A probabilistic atlas of the human brain: theory and rationale for its development. The International Consortium for Brain Mapping (ICBM). *Neuroimage* 1995;2(2):89–101.	750	36.4 (93)
87	Friston KJ, Holmes AP, Price CJ, Büchel C, Worsley KJ. Multisubject fMRI studies and conjunction analyses. *Neuroimage* 1999;10(4):385–96.	743	45.7 (80)
88	Moseley ME, Cohen Y, Kucharczyk J, Mintorovitch J, Asgari HS, Wendland MF, Tsuruda J, Norman D. Diffusion-weighted MR imaging of anisotropic water diffusion in cat central nervous system. *Radiology* 1990;176(2):439–45.	740	29.1 (97)
89[a]	Pantelis C, Velakoulis D, McGorry PD, Wood SJ, Suckling J, Phillips LJ, Yung AR, Bullmore ET, Brewer W, Soulsby B, Desmond P, McGuire PK. Neuroanatomical abnormalities before and after onset of psychosis: a cross-sectional and longitudinal MRI comparison. *Lancet* 2003;361(9354):281–8.	737	56.7 (62)
89[a]	Urenjak J, Williams SR, Gadian DG, Noble M. Proton nuclear magnetic resonance spectroscopy unambiguously identifies different neural cell types. *J Neurosci* 1993;13(3):981–9.	737	32.3 (95)
91	Fazekas F, Kleinert R, Offenbacher H, Schmidt R, Kleinert G, Payer F, Radner H, Lechner H. Pathologic correlates of incidental MRI white matter signal hyperintensities. *Neurology* 1993;43(9):1683–9.	736	33.0 (94)
92[a]	Pelizzari CA, Chen GT, Spelbring DR, Weichselbaum RR, Chen CT. Accurate three-dimensional registration of CT, PET, and/or MR images of the brain. *J Comput Assist Tomogr* 1989;13(1):20–6.	732	27.2 (98)
92[a]	Govindaraju V, Young K, Maudsley AA. Proton NMR chemical shifts and coupling constants for brain metabolites. *NMR Biomed* 2000;13(3):129–53.	732	46.7 (79)
94	Lowe MJ, Mock BJ, Sorenson JA. Functional connectivity in single and multislice echoplanar imaging using resting-state fluctuations. *Neuroimage* 1998;7(2):119–32.	730	40.7 (85)
95	Wahlund LO, Barkhof F, Fazekas F, Bronge L, Augustin M, Sjögren M, Wallin A, Ader H, Leys D, Pantoni L, Pasquier F, Erkinjuntti T, Scheltens P; European Task Force on Age-Related White Matter Changes. A new rating scale for age-related white matter changes applicable to MRI and CT. *Stroke* 2001;32(6):1318–22.	724	49.6 (71)
96	Catani M, Howard RJ, Pajevic S, Jones DK. Virtual in vivo interactive dissection of white matter fasciculi in the human brain. *Neuroimage* 2002;17(1):77–94.	693	52.0 (69)
97	Courchesne E, Karns CM, Davis HR, Ziccardi R, Carper RA, Tigue ZD, Chisum HJ, Moses P, Pierce K, Lord C, Lincoln AJ, Pizzo S, Schreibman L, Haas RH, Akshoomoff NA, Courchesne RY. Unusual brain growth patterns in early life in patients with autistic disorder: an MRI study. *Neurology* 2001;57(2):245–54.	691	47.7 (77)
98	Moseley ME, Kucharczyk J, Mintorovitch J, Cohen Y, Kurhanewicz J, Derugin N, Asgari H, Norman D. Diffusion-weighted MR imaging of acute stroke: correlation with T2-weighted and magnetic susceptibility-enhanced MR imaging in cats. *AJNR Am J Neuroradiol* 1990;11(3):423–9.	688	26.8 (99)
99	Song SK, Yoshino J, Le TQ, Lin SJ, Sun. SW, Cross AH, Armstrong RC. Demyelination increases radial diffusivity in corpus callosum of mouse brain. *Neuroimage* 2005;26(1):132–40.	681	63.8 (51)
100	Worsley KJ, Liao CH, Aston J, Petre V, Duncan GH, Morales F, Evans AC. A general statistical analysis for fMRI data. *Neuroimage* 2002;15(1):1–15.	673	48.1 (75)

[a] Two articles have the same rank because they have an equal number of citations.

Selection of journals

To identify the most-cited neuroimaging articles, journals listed under the following five subject categories of the Institute for Scientific Information (ISI) Web of Knowledge Journal Citation Reports (JCR) for the year 2014 were evaluated for inclusion in this study: "Radiology, Nuclear Medicine & Medical Imaging" (125 journals), "Neuroimaging" (14 journals), "Neuroscience" (252 journals), "Clinical Neurology" (192 journals), and "Medicine, General & Internal" (154 journals). The subject category of "Medicine, General & Internal" was included because it contains high impact interdisciplinary journals, which accepts contributions from many research communities. In addition, a search was performed in the JCR database for any journal regardless of the subject category using the title word "neuro*" (an asterisk replaces any sequence of characters), where 250 journals were identified in this search. After excluding 318 duplicated journals, a total of 669 journals were evaluated.

Identification of the 100 most-cited articles

Each of the 669 journals was then searched using the "cited reference search" in the Science Citation Index Expanded of the ISI Web of Knowledge-Web of Science (Thomson Reuters, New York, NY) on January 2016. The ISI Web of Knowledge is a multidisciplinary database providing the most relevant bibliometric information from the published scientific articles since 1945; it fully indexes >8500 major journals across 176 subject categories. The Web of Science is one of the important databases in ISI for analysis of citation counts and other academic impact information. All articles with 100 or more citations were recorded and then compiled into a single database, which allowed them to be ranked according to citation number.

The 100 most-cited neuroimaging articles were identified from this list. Authors reviewed the title and abstract of each article to ensure that they were relevant to neuroimaging. A neuroimaging article was defined as any study that 1) mainly focuses on imaging technique,

Table 2
Journals in which the 100 most-cited neuroimaging articles were published.

Journal	No. of articles	IF[a]	SNIP[b]	IPP[b]	SJR[b]
Neuroimage	38	6.357	1.903	6.259	3.549
Human Brain Mapping	12	5.969	1.498	5.231	2.535
Magnetic Resonance in Medicine	10	3.571	1.332	3.137	1.703
Radiology	5	6.867	2.759	6.489	3.148
Journal of Neuroscience	4	6.344	1.658	6.408	4.364
Annals of Neurology	3	9.977	3.263	10.157	4.946
Neurology	2	8.286	2.307	6.416	2.968
NMR in Biomedicine	3	3.044	1.117	3.280	1.357
Nature Neuroscience	2	16.095	3.358	13.678	10.503
Brain	2	9.196	2.818	9.377	4.826
Stroke	2	5.723	2.333	5.845	3.152
Journal of Cognitive Neuroscience	2	4.690	1.322	4.402	2.705
IEEE Transactions on Medical Imaging	2	3.390	2.677	4.036	1.533
New England Journal of Medicine	1	55.873	14.913	41.541	12.155
Lancet	1	45.217	13.452	31.822	11.150
Nature Reviews Neuroscience	1	31.427	7.640	29.032	17.100
Annual Review of Neuroscience	1	19.320	5.971	21.784	15.637
Cerebral Cortex	1	8.665	1.863	6.651	3.945
Archives of Neurology	1	7.419	–	–	–
Journal of Neurosurgery	1	3.737	1.910	3.634	1.741
Medical Image Analysis	1	3.654	3.282	4.473	1.728
Neurosurgery	1	3.620	1.694	2.964	1.369
American Journal of Neuroradiology	1	3.589	1.598	3.398	1.627
Journal of Magnetic Resonance Imaging	1	3.210	1.206	3.035	1.484
American Journal of Roentgenology	1	2.731	1.514	2.848	1.510
Journal of Computer Assisted Tomography	1	1.411	0.771	1.599	0.829

IF = impact factor, SNIP = source normalized impact per paper, IPP = impact per publication, SJR = SCImago journal rank.

[a] Data were collected from Journal Citation Reports for the year 2014.

[b] Data were collected from Journal Metrics for the year 2014.

utility of imaging, or diagnostic imaging interpretation for brain and spinal cord. No restrictions were placed on the patient's age for our study. Articles were excluded if they dealt purely with head and neck imaging, contained clinical decisions regarding the use of imaging studies, or focused on patient management (i.e., medication, surgery, radiation therapy, and neurointerventional procedures).

Analysis of articles

The 100 most-cited articles were reviewed and the following information was extracted according to their specific characteristics: 1) publication year, 2) journal title, 3) journal category (radiology/imaging, neuroscience/clinical neurology, or interdisciplinary), 4) IF (based on the 2014 science edition of the ISI JCR), source normalized impact per paper (SNIP), impact per publication (IPP), and SCImago journal rank (SJR) (based on 2014 Scopus Journal Metrics, Elsevier, Amsterdam, NL) of journal, 5) number of citations, 6) number of annual citations (calculated by total number of citations over the number of years and months since publication), 7) authorship, 8) department, 9) institution, 10) country, 11) article type (original article [clearly stated objectives or hypotheses and contained specifically articulated methods and results sections], review article, technical note, or systematic review/meta-analysis), 12) imaging technique used (ultrasonography, computed tomography, magnetic resonance imaging, positron emission tomography, angiography, or combined [more than one imaging technique used]), and 13) topic.

When there was more than one affiliation, the department, institution, and country of origin were defined by the affiliation provided for the first author. If the first author has multiple affiliations, the corresponding author's affiliation was used.

Data are presented by using descriptive statistics and no statistical significance tests were performed.

Table 3
Distribution of the 100 most-cited neuroimaging articles by publication date.

Publication year	No. of articles
1980–1984	2
1985–1989	4
1990–1994	14
1995–1999	31
2000–2004	38
2005–2009	10
2010–2015	1

Results

The 100 most-cited articles in the field of neuroimaging and the number of citations are presented in Table 1. The number of citations of the 100 most-cited articles ranged from 4384 to 673 (mean, 1327.5 ± 722.0; median, 1043). The number of annual citations ranged from 313.1 to 24.9 (mean, 89.2 ± 59.3; median, 66.9). When comparing the ranking of the number of annual citations to the overall amount, the change in position ranged from -62 to $+49$ with a mean absolute rank change of 14.5 ± 12.9. The top-ranking article was published in 2002 by Tzourio-Mazoyer N. et al., describing the tool of automated anatomical labeling of activations using a macroscopic anatomical parcellation (Tzourio-Mazoyer et al., 2002). This article also had the highest number of annual citations.

The most-cited articles were published in 26 of the 669 journals, led by *Neuroimage* ($n = 38$) and followed by *Human Brain Mapping* ($n = 12$). The journal categories were radiology/imaging ($n = 75$), followed by neuroscience/clinical neurology ($n = 23$), and interdisciplinary ($n = 2$). The median IF, SNIP, IPP, and SJR of these journals was 6.157 (range 1.411–55.873), 1.910 (range 0.771–14.913), 5.845 (range 1.599–41.541), and 2.968 (range 0.829–17.100), respectively (Table 2).

The period with the greatest number of most-cited articles was 2000–2004 ($n = 38$), followed by 1995–1999 ($n = 31$) (Table 3). The most frequent author was Friston KJ ($n = 11$), followed by Smith SM

Table 4
Authors who contributed three or more of the 100 most-cited neuroimaging articles.

Author	No. of articles	Position on author list (no. of articles)
Karl J. Friston	11	First (6), second (3), fifth (2)
Stephen M. Smith	9	First (4), second (1), third (1), fourth (3)
Anders M. Dale	6	First (3), third (1), fourth (1), eighth (1)
Mark Jenkinson	5	First (2), second (2), third (1)
J. Michael Brady	5	Second (1), third (2), twelfth (1) sixteenth (1)
Alan C. Evans	5	Third (1), sixth (1), seventh (2), eleventh (1)
Keith J. Worsley	4	First (3), fifth (1)
Bruce Fischl	4	First (2), second (1), third (1)
John Ashburner	4	First (2), second (1), third (1)
Timothy E.J. Behrens	4	First (2), fifth (1), eleventh (1)
Mark W. Woolrich	4	First (1), third (2), fifth (1)
Martin I. Sereno	4	Second (3), third (1)
Andrew P. Holmes	4	Second (3), fourth (1)
Yoram Cohen	4	Second (3), fourth (1)
Heidei Johansen-Berg	4	Second (2), third (1), sixth (1)
Richard S.J. Frackowiak	4	Third (1), sixth (3)
Paul M. Matthews	4	Fifth (1), tenth (1), thirteenth (1), seventeenth (1)
Michael E. Moseley	3	Firth (3)
Sheng-Kwei Song	3	First (3)
Susumu Mori	3	First (2), fifth (1)
Thomas E. Nichols	3	First (1), third (1), fifth (1)
Yongyue Zhang	3	First (1), second (1), fourteenth (1)
Eric C. Wong	3	Second (2), third (1)
John Kucharczyk	3	Second (1), third (1), sixth (1)
Peter C.M. van Zijl	3	Second (1), fourth (2)
Jan Mintorovitch	3	Third (2), fourth (1)
James S. Hyde	3	Fourth (2), fifth (1)
Anne H. Cross	3	Fifth (1), sixth (2)

Table 5
Institutions which contributed the 100 most-cited neuroimaging articles.

Department, institution (country)	No. of articles
Oxford Centre for Functional Magnetic Resonance Imaging of the Brain, John Radcliffe Hospital (United Kingdom)	10
Wellcome Trust Centre for Neuroimaging, University College London (United Kingdom)[a]	9
Nuclear Magnetic Resonance Center, Massachusetts General Hospital/Harvard Medical School (United States)	6
Department of Radiology, University of California (United States)	5
Department of Radiology, Washington University School of Medicine (United States)	4
Department of Mathematics and Statistics, McGill University (Canada)	3
Department of Radiology, Hospital of the University of Pennsylvania (United States)	3
Department of Radiology and Radiological Science, Johns Hopkins University School of Medicine (United States)	3
Biophysics Research Institute, Medical College of Wisconsin (United States)	2
Brain Mapping Center, UCLA School of Medicine (United States)	2
Department of Psychology, Stanford University (United States)	2
Department of Neurology, Washington University School of Medicine (United States)	2
Department of Neuroscience, School of Medicine, University of California (United States)	2
AT&T Bell Laboratories, Murray Hill (United States)	1
Center for Cognitive Neurosciences, Duke University (United States)	1
Child Psychiatry Branch, National Institute of Mental Health (United States)	1
Cognitive Neuropsychiatry Research and Academic Unit, and Melbourne Neuropsychiatry Centre, Mental Health Programme, Department of Psychiatry, University of Melbourne and Sunshine Hospital (Australia)	1
Department of Anatomy and Neurobiology, Boston University School of Medicine (United States)	1
Department of Anatomy, University College London (United Kingdom)	1
Department of Biomedical Engineering, Faculty of Medicine, University of Alberta (Canada)	1
Department of Biophysics, Hunterian Institute, Royal College of Surgeons of England (United Kingdom)	1
Department of Biostatistics, University of Michigan (United States)	1
Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology (United States)	1
Department of Chemistry, Washington University (United States)	1
Department of Clinical Neuroscience, NEUROTEC, Karolinska Institutet, Huddinge University Hospital (Sweden)	1
Department of Diagnostic Radiology, Vrije Universiteit Hospital, Amsterdam (The Netherlands)	1
Department of Medical Physics, University of Wisconsin (United States)	1
Department of Neurology, Beth Israel Hospital (United States)	1
Department of Neurology, Harvard University (United States)	1
Department of Neurology, Karl-Franzens University (Austria)	1
Department of Neurology, Medical College of Wisconsin (United States)	1
Department of Neurosurgery, University of Bern (Switzerland)	1
Department of Psychiatry, Harvard Medical School (United States)	1
Department of Psychiatry, PET Facility, University of Pittsburgh (United States)	1
Department of Psychiatry, University of Michigan (United States)	1
Department of Psychology, Carnegie Mellon University (United States)	1
Department of Psychology, Columbia University (United States)	1
Department of Psychology, University of Alberta (Canada)	1
Department of Radiation Oncology, University of Chicago (United States)	1
Department of Radiology, Medical College of Wisconsin (United States)	1
Department of Radiology, Wake Forest University Health Sciences Center (United States)	1
Department of Statistics, Carnegie Mellon University (United States)	1
Division of Psychiatric Neuro-Imaging, Johns Hopkins University (United States)	1
Groupe de Biophysique, Ecole Polytechnique, Palaiseau (France)	1
Groupe d'Imagerie Neurofonctionnelle, UMR 6095 CNRS CEA (France)	1
Howard Hughes Medical Institute, Salk Institute for Biological Studies (United States)	1
Institut für Medizin, Forschungszentrum Jülich (Germany)	1
Laboratoire de Neurosciences Cognitives et Imagerie Cérébrale (France)	1
Max-Planck-Institut für biophysikalische Chemie (Germany)	1
Montréal Neurological Institute, McGill University, McConnell Brain Imaging Centre (Canada)	1
MRC Cognition and Brain Sciences Unit, Cambridge (United Kingdom)	1
Multiple Sclerosis NMR Research Group, Institute of Neurology, London (United Kingdom)	1
Neuroimaging Branch, National Institute of Neurological Diseases and Stroke, National Institutes of Health (United States)	1
Neurology Service, Massachusetts General Hospital, Boston (United States)	1
Psychiatry Service, Palo Alto Department of Veterans Affairs Medical Center (United States)	1
Research Department of Psychiatry, Cambridge University, Addenbrooke's Hospital (United Kingdom)	1
Research Imaging Center, University of Texas Health Science Center at San Antonio (United States)	1
Section of Old Age Psychiatry, Institute of Psychiatry (United Kingdom)	1
Section on Tissue Biophysics and Biomimetics (United States)	1
Service Hospitalier Frédéric Joliot, CEA (France)	1

Note: For the purpose of our research, institution of origin was defined by the address provided for the first author. If the first author has affiliation to more than one institution, the corresponding author's affiliation was used for the origin of the article.

[a] Combined from Wellcome Department of Cognitive Neurology and Wellcome Department of Imaging Neuroscience.

($n = 9$), and Dale AM ($n = 6$) (Table 4). The most common departmental affiliations of authors were the radiology or imaging center (including magnetic resonance and brain mapping center) ($n = 37$), followed by neuroscience (including neurology and neurosurgery) ($n = 22$), and psychiatry and psychology ($n = 14$). Other affiliations of first authors included physics ($n = 7$), statistics ($n = 5$), and engineering ($n = 3$). Based on the first author's affiliation, the institution with the most articles was the Oxford Centre for Functional Magnetic Resonance Imaging of the Brain at John Radcliffe Hospital ($n = 10$), followed by Wellcome Trust Centre for Neuroimaging at University College London ($n = 9$), and Nuclear Magnetic Resonance Center at Massachusetts General Hospital/Harvard Medical School ($n = 6$) (Table 5). The majority of the articles originated in the United States (U.S.) ($n = 58$), distantly followed by United Kingdom ($n = 25$) (Table 6).

Article type was most frequently original article ($n = 63$), followed by technical note ($n = 18$), and review article ($n = 16$) (Table 7). Magnetic resonance imaging ($n = 85$) was the most frequently used imaging technique (Table 8). The most common topic was new imaging technique or technology ($n = 45$), followed by functional neuroimaging ($n = 28$) (Table 9).

Discussion

Citation analysis is the bibliometric process that examines the frequency and patterns of citations in articles (Garfield, 1972). The number of citations is widely used to assess the impact of an individual article and measure the quality of a journal (Moed, 2009). In addition, it is also used to identify the classic articles based on the number of citations.

Citation classics are defined as articles that rank in the highest percentile of citations in a particular scientific field. These articles have a significant influence upon the development of a given discipline because they provide the basis for new concepts, methods, or techniques (Garfield, 1987). The list of the most-cited articles in a certain specialty is useful for several reasons (Garfield, 1972; Callaham et al., 2002). First, it reveals useful and interesting information about scientific progress such as topics, authors, institutions, journals, and trends of research. Second, it offers the reader a fascinating insight into how research fields have evolved over time. Third, it may help residency and fellowship directors pursue and tailor their research interests in a particular medical field.

The 100 most-cited articles in the field of neuroimaging were cited between 4384 and 673 times. The number of citations in our study is higher than those observed in other radiological specialties such as interventional radiology and radiology of trauma (Crockett et al., 2015;

Table 6
Countries of origin of the 100 most-cited neuroimaging articles.

Country	No. of articles
United States	58
United Kingdom	25
Canada	6
France	4
Germany	2
Australia	1
Austria	1
Sweden	1
Switzerland	1
The Netherlands	1

Note: For the purpose of our research, country of origin was defined by the address provided for the first author. If the first author has affiliation to more than one institution, the corresponding author's affiliation was used for the origin of the article.

Dolan et al., 2015). One can hypothesize that the size of the scientific community might be the main reason for this difference. However, the number of citations in neuroimaging is even comparable to those of whole radiology classic articles (Yoon et al., 2013; Brinjikji et al., 2013; Pagni et al., 2014). It can be explained by the fact that all journals that could potentially publish neuroimaging articles, regardless of the subject category, were included in our analysis.

In addition, we also analyzed the number of annual citations of articles. We believe that this method can be used instead of the total citations for time since publication to evaluate the current impact of the article. The number of annual citations produced substantial shifts in the rank for the 100 most-cited articles. Articles with a high total citation count but low number of annual citations are more likely historically important and may not reflect the current impact. In contrast, articles with both high total citation count and number of annual citations still retain relevance for current researchers.

In terms of publication time, 69% of the most-cited neuroimaging articles were published between 1995 and 2004. This result is consistent with the previous results of general radiology (Yoon et al., 2013; Brinjikji et al., 2013; Pagni et al., 2014) and radiological subspecialties (Crockett et al., 2015; Dolan et al., 2015) but in contrast with those of other medical specialties, which revealed that a majority of highly cited articles were published before 1990 (Paladugu et al., 2002; Baltussen and Kindler, 2004; Ponce and Lozano, 2010; Brandt et al., 2010; Kelly et al., 2010; Shadgan et al., 2010). This difference can be explained by the relatively recent evolution and rapid development in the field of radiology, rather than the increase in published articles and development of bibliographic databases.

We have observed that 58% of articles in the top 100 list originated from the U.S., which is similar to results of previous citation classic studies in the field of whole radiology (46%–61%) or radiological subspecialties (Yoon et al., 2013; Brinjikji et al., 2013; Pagni et al., 2014). It can be attributed to the large size of the scientific community and the abundant financial resources of the U.S. Moreover, it has also been reported that U.S. authors usually prefer to publish in U.S. journals and preferentially cite local papers (Campbell, 1990). However, our results are less concentrated in the U.S. compared to those of interventional radiology (67%) (Crockett et al., 2015) and radiology of trauma (86%) (Dolan et al., 2015).

Table 7
Types of article of the 100 most-cited neuroimaging articles.

Type of article	No. of articles
Original article	63
Basic	37
Clinical	18
Animal	8
Technical note	18
Review article	16
Meta-analysis	3

With regard to journals, 25% of the most-cited neuroimaging articles have been published in non-imaging journals, including neuroscience/clinical neurology and interdisciplinary journals. This tendency primarily reflects the impact of neuroimaging articles on other clinical specialties. Furthermore, 63% of the first authors had an affiliation other than radiology. The broad representation of journals and departments in our list may demonstrate that one of the major features of the most-cited articles is wide audience of physicians and applicability to other research fields. Now, publication across disciplines is an important trend in scientific publications. A recent study reported that 35.7% of articles published by radiologists were published in non-radiology journals in 2010 (Yun et al., 2013).

Last, 45% of the most-cited articles were those that presented new imaging techniques or technologies (e.g. functional imaging, diffusion tensor imaging, and diffusion-weighted image). The frequent citation of technical articles appears to be unique to neuroimaging, as citation analyses in other medical disciplines (Paladugu et al., 2002; Baltussen and Kindler, 2004; Ponce and Lozano, 2010; Brandt et al., 2010; Kelly et al., 2010; Shadgan et al., 2010) and even in radiology (Chew, 1988; Yoon et al., 2013; Brinjikji et al., 2013; Pagni et al., 2014; Crockett et al., 2015; Dolan et al., 2015) have demonstrated that most citation classics are clinical in nature. This difference is likely to reflect the relative importance of imaging techniques on the progress of neuroimaging as a whole. It also highlights the high dependence of neuroimaging on advancements in basic imaging fields such as physics, statistics, engineering, and computer science.

Although citation analysis is an established method of objectively identifying classic articles within a specialty, there are inherent potential elements of bias in an analysis of this type. Between 2013 and 2014, three bibliometric analyses of the 100 most-cited articles in the field of radiology (or imaging) have been published (Yoon et al., 2013; Brinjikji et al., 2013; Pagni et al., 2014). Surprisingly, there were only 18 common articles in three citation classic lists, even if the time interval between data collection was less than one year. There could be several reasons for this finding. First, one major reason is that the marked difference in the number of selected radiology journals. The number of selected journals for citation classics ranged from 12 to 116 in their studies. Second, these studies used different inclusion and exclusion criteria for selection of articles (for example, articles that dealt exclusively with nuclear medicine or radiation oncology). Third, the list of most-cited articles is dynamic, which ultimately changes with time and advances in the field. Finally, the accuracy of citation analysis is dependent on the accuracy of the citation count obtained from the search engine that is used. There are several citation databases such as Web of Science, Scopus, and Google Scholar (Google Inc., Mountain View, CA). Thus, it is possible that the citation count from these databases differs (Bakkalbasi et al., 2006; Kulkarni et al., 2009). For comparison, we

Table 8
Imaging techniques used in the 100 most-cited neuroimaging articles.

Imaging technique	No. of articles
Magnetic resonance imaging	85
Functional	44
Diffusion tensor imaging	16
Diffusion-weighted image	3
Volumetry	3
Spectroscopy	2
Dynamic imaging	2
Conventional	15
Positron emission tomography	2
Computed tomography	1
Ultrasonography	1
Combined[a]	11

[a] More than one imaging technique used.

Table 9
Main topics covered in the 100 most-cited neuroimaging articles.

Topic	No. of articles
New imaging technique or technology	45
Functional neuroimaging	28
Age-related change in brain	4
Brain anatomy	4
Demyelination	4
Ischemia/infarction	3
White matter lesion	3
Psychosis	3
Dementia	2
Hemorrhage	2
Others	2

obtained total citation counts of the top 10 papers in our list from Web of Science, Scopus, and Google Scholar databases (retrieved on May 28, 2016). We found that Google Scholar (4372 ± 1027) and Scopus (3438 ± 788) had higher average number of citations for these 10 articles than Web of Science (3187 ± 732). Because Google Scholar and Scopus databases have wider local and international journal coverage, they generally provide higher citation counts than Web of Science. In citation classic studies in the field of radiology, one study (Brinjikji et al., 2013) used the Scopus Library database while two others (Yoon et al., 2013; Pagni et al., 2014) used Web of Science. In our study, we sought to use Web of Science, which has been shown to be the most commonly used and robust method for clinical medicine (Paladugu et al., 2002; Baltussen and Kindler, 2004; Ponce and Lozano, 2010; Brandt et al., 2010; Kelly et al., 2010; Shadgan et al., 2010).

There are several inherent limitations, which have been highlighted in previous citation analyses using similar methods. First, the overall number of citations of an article could be influenced by its publication year because citations accumulate over time; older articles have had more time to be cited than recent articles (Pepe and Kurtz, 2012). In response, we used the time-adjusted annual citation count (number of citations per year) to provide the relative impact of an article, regardless of the duration since publication. Second, the number of citations can be influenced by not only the quality of the article, but also many other factors such as obliteration by incorporation (i.e., the phenomenon that information from highly influential articles has been incorporated into common knowledge such that they are not explicitly cited), omission bias (i.e., tendency to not cite competitors or sources contradictory to one's own results), self-citation, referencing high-IF core journals in the field of study, attitude toward citing review articles over original research, and national or language preferences (Dumont, 1989; Marx and Wanitschek, 2001; Braun, 2003).

A strength of our study was that we compiled a more comprehensive list of the most-cited neuroimaging articles across all peer-reviewed scientific journals. The majority of previous radiology citation classic studies (Yoon et al., 2013; Brinjikji et al., 2013; Pagni et al., 2014; Crockett et al., 2015) restricted their searches to only radiology or imaging journals to gain the most-cited articles, thus excluding important articles from other discipline or interdisciplinary journals. In our study, however, a total of 669 journals regardless of the subject category that could potentially publish neuroimaging articles were included for the production of the current list of 100 most-cited articles. Consequently, we could identify all classic articles published in not only radiology/nuclear medicine/imaging journals but clinical neurology/neuroscience disciplines and high-IF interdisciplinary journals.

Conclusions

We identified and bibliometrically analyzed the 100 most-cited articles in the field of neuroimaging. Our 100 most-cited articles list provides an insight into historical developments and allows for the recognition of important advances in the field of neuroimaging.

Conflict of interest

The authors declare no competing financial interests.

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