The First 50 Years of Total Hip Arthroplasty

Lessons Learned

William H. Harris MD, DSc

Published online: 4 November 2008
© The Association of Bone and Joint Surgeons 2008

Abstract Fifty years have passed since the first total hip arthroplasty of the modern era was performed. At this, the vantage point, it is reasonable to review these five decades, inquiring behind the single dominating observation that, in its current form, this operation is one of the most successful of all surgical procedures for the management of end-stage human disease. What are the generic lessons that can be derived from the experience? Succinctly, five major observations appear valuable. They are “skunk works,” “Pasteur’s motto,” “the totally unexpected,” “research solutions,” and “the role of alternatives.” “Skunk works,” an industrial management term, might be characterized as an innovative endeavor that is offline and off-budget resulting from the relentless pursuit of a vivid dream by creative zealots who eschew defeat. Pasteur’s motto dealt with serendipity, which was crucial to total hip arthroplasty progress. The totally unexpected is represented by an entirely new manmade disease, “periprosthetic osteolysis.” The research solutions are represented by the complex, sophisticated contemporary research that has unraveled periprosthetic osteolysis and suggested modes of correction. Finally, the application of “alternatives” has characterized major progress. Importantly, these, or similar

generic observations, may provide insights into important progress in the future.

Introduction

The first 50 years of THA in the modern era has passed. Thus, it is reasonable to examine retrospectively this five-decade experience and inquire into what lessons can be derived from such a review, lessons that lie behind the single dominant observation that in its present form, THA represents one of the most successful major operations ever devised for the treatment of end-stage human disease.

Many ideas concepts, developments, and inventions have contributed to the current state of the art, but a simple listing of each of these landmarks would be less valuable than a broader, generic assessment of the major contributions. Such a broad overview, moreover, could be helpful for accessing key ingredients in both future development of THA and for the development of other parallel innovative endeavors.

The five broad important observations, some obvious and some not, that can be drawn from this 50-year experience can be highlighted as follows: (1) skunk works; (2) Pasteur’s motto; (3) the totally unexpected; (4) research works; and (5) the role of alternatives.

The Five Observations

A brief description of these five lessons and their roles in 50 years of progress follows.

The definition of “skunk works” by the McKenzie Company, the industrial consultants, may be paraphrased to be a very nontraditional innovative effort, which is

The author has received funding from the William H. Harris, MD, Foundation.

W. H. Harris
Department of Orthopaedic Surgery, Harvard Medical School,
Boston, MA, USA

W. H. Harris (✉)
Harris Orthopaedic Biomechanics and Biomaterials Laboratory
and the Adult Reconstruction Unit, Massachusetts General
Hospital, 55 Fruit Street, GRJ 1126, Boston, MA 02114, USA
e-mail: wharrishm@hotmail.com

offline, off-budget, remarkably innovative, driven by creative zealots, uninhibited by failure, and relentless.

The development of THA, particularly in the guise of Sir John Charnley, is a classic “skunk works.” In the Teflon experience, the short-term clinical results were nearly as stunning as the incredibly high failure rates [4]. Recall that at one time, the single most common operation Charnley did was resection arthroplasty on a failed Teflon THA. Yet, the contemporary overall magnificent results of THA speak to the unbelievable drive, intelligence, dedication, and persistence of a few, primarily Sir John Charnley, but also Boutin and McKee. One of the greatest scientists of all time, Louis Pasteur, had a motto that might loosely be translated as “Chance favors the prepared mind.” This is serendipity. The serendipity examples in the development of THA have unique clarity. In brief, Charnley’s question dealing with a plastic grouting material for fixation of the femoral component was addressed to Dennis Smith, a chemist working for a PhD degree at Turner Dental Hospital in Manchester, UK [4]. Charnley asked “what plastics could be used to hold a hip prosthesis in the femur?” Smith’s answer, “methylmethacrylate,” was based on the use of methylmethacrylate in the mouth, which is far from being equivalent to its use in the internal milieu of the body. However, his answer worked. It is still working 50 years later. That is serendipity.

As Pasteur’s experience reflects, had Charnley’s mind not been prepared to ask the question and then act on the answer from Dennis Smith, although the answer was unsupported by fact, THA would have been set back decades.

Similarly, the story of Charnley’s introduction to ultra-high-molecular-weight polyethylene (UHMWPE), again central to the entire 50-year effort and the savior of his Teflon experience, is pure serendipity. An UHMWPE salesman made the unusual deduction that because his polyethylene was used in making gears, it might be acceptable to use in the body for THAs. He visited Charnley’s laboratory technician. Charnley dismissed the material. Charnley’s laboratory technician tested this material at night without telling his boss and history was made [4].

The third dominating lesson is the importance of the “totally unexpected.” The admonition to be learned is “Always expect the unexpected.” With the introduction of UHMWPE into THA in November 1962, the world of THA changed radically. The early wear results were so good and the durability so much improved over Teflon that the intensity of most subsequent research focused narrowly on an entirely different set of problems, namely sepsis, fixation, and fatal pulmonary emboli.

The fatal pulmonary embolism rates of one in every 50 patients [5, 6], infection rates of 9.5% to 11% [3, 25], and the increasing failure of cement fixation drove

unprecedented scientific programs that have now very successfully protected most patients against all three of these complications.

However, unknowingly, although the focus was so intently on these issues, the totally unexpected, namely periprosthetic osteolysis [9, 23, 24], was totally unrecognized and severely undermined the long-term success of THA. Specifically because it was very late to develop, insidious, clinically silent, and widespread, it was enigmatic. What was causing this late massive bone loss that resembled metastatic malignancy more closely than any other known pathology of that day?

Because the remarkably slower wear of the UHMWPE was very reassuring, no one envisioned that a unique type of wear was occurring: the generation of submicron particles through a previously unknown wear mechanism [11] and, even more alarming, the destructive macrophage-induced response to these particles produced periprosthetic osteolysis [10].

The “unexpected” lay in the fact that the very process of creating a successful artificial total joint had inadvertently produced, for the first time in human history, an *in vivo* wear machine that spewed out a zillion tiny particles *in vivo* over decades of time [12]. Thus, a new, unique, manmade, “never seen before” disease was created without realizing it: the totally unexpected.

The fourth lesson lies in the unraveling of this bizarre process of periprosthetic osteolysis. The solution of this enigma speaks to the strength of contemporary medical research in the Western world. Periprosthetic osteolysis is now extensively understood in terms of its mechanism of action, the material science involved, and the complex molecular biology that underlies it [10, 11]. From a myriad of multifaceted investigations have come not only an understanding of the nature of the problem, but also several very promising but widely disparate modes of reduction, prevention, and/or treatment of the problem [13, 16, 19, 21, 22]. At a different time in human history, such could not have occurred. At a different place in the world during this same time, other than Western civilization with its emphasis on science and its resources, solutions would be unlikely. Research works.

Finally, the fifth major lesson from these first 50 years is the role of alternatives. Galante and Rostoker and coworkers received a Kappa Delta Award in 1970 on a strange new idea [7], namely bony ingrowth, a biologic form of component fixation. Thirty-eight years later, this is the dominant form of fixation for THA throughout North America and a strong contender worldwide. Just as Charnley and McKee thought “outside the box” in their quest for a totally artificial hip, Galante and Rostoker overturned the “grout” concept of skeletal fixation and thought biologically.

Similarly, the alternatives of ceramic [8] and of metal-on-metal [14, 20] articulations have proven successful. Moreover, subsequent to the new understanding of the mechanisms of lysis from UHMWPE in humans, the innovations of crosslinking plus melting [14, 15, 20] or crosslinking with added antioxidants [17, 18] have reestablished metal-on-crosslinked polyethylene as a leading choice for articulation [1]. These alternate bearings have also decreased loosening of the components, increased durability of the operations, and increased the opportunity to operate successfully on younger patients. Moreover, the alternative bearings have substantially improved the issues of range of motion, dislocation, and treatment of dislocation [2].

Discussion

A singular limitation of the selection of these five “lessons” from the experience of the first 50 years of THA is that it represents the analysis of a single observer. One of the strengths may be that the single observer has followed and been a participant in the experience throughout 42 of those years. Perhaps strength lies in looking broadly at the types of processes that dominated the progress over that duration rather than listing multiple individual milestones.

In North America, the femoral components implanted are mostly cementless. The acetabular components used are largely cementless. Alternate bearings dominate with a growing movement toward heads 32 mm or larger. Does this mean we have abandoned Charnley, as a superficial reading would suggest? Far from it. His innovation and his unswerving pursuit of his dream underlie everything that has been done in the past 50 years. Indeed, during those five decades, the process of THA has been built better, much better. In the future, more and better things will come, but in that process, this experience emphasizes that it is crucial to keep clearly in mind these five key features, namely “skunk works,” Pasteur’s motto, the totally unexpected, the power of contemporary medical research, and the role of alternatives as well, obviously, as-yet additional unanticipated lessons.

References

1. Bragdon CR, Kwon YM, Geller JA, Greene ME, Freiberg AA, Harris WH, Malchau H. Minimum 6-year followup of highly crosslinked polyethylene in THA. *Clin Orthop Relat Res*. 2007;465:122–127.
2. Burroughs BR, Rubash HE, Harris WH. Femoral head sizes larger than 32 mm against highly crosslinked polyethylene. *Clin Orthop Relat Res*. 2002;405:150–157.
3. Charnley J. A clean-air operating enclosure. *Br J Surg*. 1964;51:202–205.
4. Charnley J. *The Man and the Hip*. New York, NY: Springer; 1990:120–143.
5. Coventry MB, Nolan DR, Beckenbaugh RD. ‘Delayed’ prophylactic anticoagulation: a study of results and complications in 2,012 total hip arthroplasties. *J Bone Joint Surg Am*. 1973;55:1487–1497.
6. Crawford WJ, Hillman F, Charnley J. A clinical trial of prophylactic anticoagulant therapy in elective hip surgery. In: *Internal Publication 14*. Wigan, UK: Centre for Hip Surgery, Wrightington Hospital; 1968.
7. Galante J, Rostoker W, Lueck R, Ray RD. Sintered fiber metal composites as a basis for attachment of implants to bone. *J Bone Joint Surg Am*. 1971;53:101–114.
8. Hamadouche M, Boutin P, Daussange J, Bolander ME, Sedel L. Alumina-on-alumina total hip arthroplasty. *J Bone Joint Surg Am*. 2002;84:69–77.
9. Harris WH, Schiller AL, Scholler JM, Freiberg RA, Scott R. Extensive localized bone resorption in the femur following total hip replacement. *J Bone Joint Surg Am*. 1976;58:612–618.
10. Jacobs JJ, Roebuck KA, Archibeck M, Hallab NJ, Glant TT. Osteolysis: basic science. *Clin Orthop Relat Res*. 2001;393:71–77.
11. Jasty M, Goetz DD, Bragdon CR, Lee KR, Hanson AE, Elder JR, Harris WH. Wear of polyethylene acetabular components in total hip arthroplasty: an analysis of one hundred and twenty-eight components retrieved at autopsy. *J Bone Joint Surg Am*. 1997;79:349–358.
12. Kabo JM, Gebhard JS, Loren G, Amstutz HC. In vivo wear of polyethylene acetabular components. *J Bone Joint Surg Br*. 1993;75:254–258.
13. Maloney WJ, Herzog W, Paprosky W, Rubash HE, Engh CE. Treatment of pelvic osteolysis association with a stable acetabular component inserted without cement as part of a total hip replacement. *J Bone Joint Surg Am*. 1997;79:1628–1634.
14. McKellop H, Shen FW, Lu B, Campbell P, Salovey R. Development of an extremely wear-resistant ultra high molecular weight polyethylene for total hip replacements. *J Orthop Res*. 1999;17:157–167.
15. Muratoglu OK, Bragdon CR, O’Connor DO, Jasty M, Harris WH. A novel method of cross-linking ultra-high molecular weight polyethylene to improve wear, reduce oxidation, and retain mechanical properties. Recipient of the HAP Paul Award. *J Arthroplasty*. 2001;16:149–160.
16. Nehme A, Lewallen D, Hanssen AD. Modular porous metal augments for treatment of severe acetabular bone loss during revision hip arthroplasty. *Clin Orthop Relat Res*. 2004;429:201–208.
17. Oral E, Christensen SD, Malhi AS, Wannomae KK, Muratoglu OK. Wear resistance and mechanical properties of highly cross-linked UHMWPE doped with vitamin E. *J Arthroplasty*. 2006;21:58–59.
18. Oral E, Wannomae KK, Hawkins N, Harris WH, Muratoglu OK. α -Tocopherol-doped irradiated UHMWPE for high fatigue resistance and low wear. *Biomaterials*. 2004;25:5515–5522.
19. Schreurs BW, Bolder SBT, Gardeniers JMW, Verdonschot N, Sloof TJJH, Veth RPH. Acetabular revision with impacted morcellized cancellous bone grafting and a cemented cup. A fifteen to twenty year follow up. *J Bone Joint Surg Br*. 2004;86:492–497.
20. Silva M, Heisel C, Schmalzried TP. Metal-on-metal total hip replacement. *Clin Orthop Relat Res*. 2005;430:53–61.
21. Sporer SM, Paprosky WG. The use of trabecular metal acetabular component and trabecular metal augment for severe acetabular defects. *J Arthroplasty*. 2006;21(Suppl 2):83–86.

22. Tsiridis E, Narvani AA, Haddad FS, Timperley JA, Gie GA. Impaction femoral allografting and cemented revision for periprosthetic femoral fractures. *J Bone Joint Surg Br.* 2004;86:1124–1132.
23. Willert H-G, Semlitsch M. Reactions of the articular wear capsule to wear products of artificial joint prostheses. *J Biomed Mater Res.* 1977;11:157–164.
24. Willert H-G, Semlitsch M. Tissue reactions to plastic and metallic wear products of joint endoprostheses. *Clin Orthop Relat Res.* 1996;333:4–14.
25. Wilson PD Jr, Amstutz HC, Czernicki A, Salvati EA, Mendes DG. Total hip replacement with fixation by acrylic cement. *J Bone Joint Surg Am.* 1972;54:207–236.