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Technology-related Factors Contributing to Labour Intensification of Surgical Production*

P. LYNNE JOHNSTONE

ABSTRACT *The late 1980s heralded the start of what is widely acknowledged as a period of enormous technological change in surgery, particularly, but not limited to, minimum access surgery either displacing conventional open surgical techniques or providing new opportunities for surgical treatments. This article discusses the main technology-related factors contributing to the significant, but unanticipated, labour intensification of surgical production within operating departments—reasons that are not consistent with the pervasive theme of the techno-economic literature that generally equates 'new technology' with automation, labour displacement, work simplification, and the economic benefits accruing to an organisation.*

Keywords: surgery; technological change; complexity; labour process.

Introduction

The research findings reported in this article were among those of a larger study that explored the process and organisational consequences of the adoption of new surgical 'artefact' technologies (i.e. surgical instruments, biomedical machines, and associated surgical materials) in the operative phase of surgical production within operating departments in hospitals.[1] Five key questions guided the inquiry. One concerned the technical characteristics of these artefacts and their functional roles in surgical production. The others concerned the reasons for their adoption, the expected and actual organisational consequences of their adoption, and the processes whereby the decisions are made to adopt them. Consequently, the research explored various organisational structural aspects, including the work-related consequences of new *artefact* adoption in surgery, of the surgical production process within operating departments, and undertook a detailed study of six representative, high volume surgical procedures in which new *surgical artefacts* were employed during the 10 years to 1998.

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Throughout this article, the term *surgical production* refers to all of those activities that contribute to producing any diagnostic or therapeutic procedure undertaken within the operating department (OD) of a hospital. It does not include technologies employed in the related fields of anaesthetics or patient recovery. The term *surgical technologies* refers to all *artefacts, techniques* and *organisations* contributing to surgical production. Surgical technologies are distinguished according to whether they are employed during the course of the procedure (i.e. *intra-operative technologies*), or before or after the procedure (i.e. *perioperative technologies*).

The period since the late 1980s has been characterised by rapid increases in the relative cost of the provision of health services. Both in Australia and overseas, this has been largely attributed to the rapid growth in the availability and application of increasingly complex medical technologies which are generally expensive to acquire and operate.[2] These technologies, particularly in surgery, have resulted in significant reductions in the length of time an individual spends in hospital and, therefore, in the cost of the pre- and post-operative care component of an episode of care in a hospital.[3] The high cost of new surgical technologies has resulted in cost shifting to the OD but, despite the overall trend of rising health care costs, the inflation-adjusted average total cost per *surgical* episode of care is reported to have been fairly steady.[4]

The author has reported elsewhere[5] the finding of the present research that significant increases occurred in the human labour input to surgical production within ODs during the 10 years, but argued that the 'real' cost of these increases has not been factored into the Australian Government's cost estimations on which its conclusions about 'fairly steady' surgical costs were based. These increases are evidenced by both a 15.85% increase in the average operating time of all procedures (n = 30,345) and, hence, the *direct* (i.e. *intra-operative*) human labour input, and significant increases in the volume of *indirect* (i.e. *perioperative*) human labour input to surgical production within ODs. Changes in the latter were determined by studying six representative high volume procedures that had undergone technological change during the 10 years. Increases ranged from around 37% in the case of total knee replacement to 130% in the case of hysteroscopy (i.e. endoscopic examination of the uterus) employed as a complementary technology with diagnostic curettage of the uterus.

The present article discusses the main technology-related factors contributing to the unanticipated intensification of the labour process, which derive principally from:

- the *enabling*, not automating, characteristic of new surgical instruments and biomedical machines;
- the phenomenon of *alternative* and *complementary technologies*: new surgical technology not necessarily displacing a pre-existing surgical technology;
- frequent, ad hoc, and often short-lived changes in surgical technologies; and
- increased volume, technical complexity and specialist characteristics of new intra-operative artefacts.

Research Questions

The following two of the study's five research questions yielded the data that have been synthesised to present the findings reported in this article:

1. What are the dominant technical characteristics and functional goals of new intra-operative artefacts adopted between 1988 and 1998?
2. What are the actual consequences for surgical production within operating departments of new intra-operative artefact adoption?

Theoretical Background

There is a strong manufacturing bias in the organisational literature on technological change because most studies on the topic have been carried out in production organisations, where the outputs are tangible as opposed to the service sector, where what is produced is 'intangible, impermanent or immaterial'.[6] On the one hand, this could be viewed as problematic, but the very dominance of this literature is indicative of the gap that exists on the topic of new artefact adoption in health services and, in particular, in surgical production occurring within operating departments.

This review of the literature commences with an historical snapshot of innovations in medicine and then examines the concept of health care technologies. It concludes with an examination of what the organisational literature has to say about the dominant technical goals of new artefact technologies and the expected organisational benefits of adopting them.

Innovations in Medical Care

Innovations in the diagnosis and treatment of illness are not unique to recent decades or the twenty-first century, but pervade all cultures and periods of human history. In our modern era, the volume of medical research and its accompanying literature is evidence of the ongoing nature of medical experimentation and changes/innovation in routine medical practice.[7] From time to time, major discoveries changed the course of medical history. For example, Louis Pasteur's discovery of bacteria in the mid-nineteenth century founded the science of microbiology with the 'germ theory of disease'. The discovery of penicillin in 1928 by Sir Alexander Fleming led to penicillin subsequently becoming the 'big gun' in the pharmaceutical arsenal for the treatment of bacterial infections.[8]

More recently, another significant medical milestone occurred in France. In 1987 a human gall bladder was surgically removed for the first time using a minimally invasive technique known as a *laparoscopic cholecystectomy*, rather than the established 'open' large incision approach.[9] This event was the forerunner of most of the subsequent changes in surgical technologies that constitute the focus of the present research.

Health Care Technologies

Richardson's broad definition of new technology in health care 'as any change in the method or organisation of treatment'[10] is consistent with Macdonald's generic definition, which describes technology first in *process* terms—'the sum of all knowledge, that allows things to be done'[11]—and then in terms of the possible application of something tangible, such as a machine, to the process.

The health economist, Doessel, distinguishes changes in medical technology in terms of *product* and *process innovation*.[12] Both potentially have physical and abstract elements. As his starting point, he uses Blaug's 1963 definitions whereby *process innovations* are 'novel ways of making old goods' and *product innovations* are 'old ways of making novelties'.[13] Doessel limits his working definition of *product innovation* to the creation of a new product or service for a medical condition for which there was no prior product or service, and exemplified this with developments in the treatment of end-stage kidney disease. He proposed that the advent of renal dialysis represented *product innovation* because there had previously been no treatment available for the condition. However, he describes kidney transplants as a *process innovation* because it represents a new and different way of treating end-stage kidney disease. Hence, he regards 'the product' as the treatment of end-stage renal disease, and it seems of no consequence to him that what he calls a process innovation (kidney transplant) involves very different techniques, hardware and outcomes.

More recently, Pusić used Tushman and Anderson's 1986 definitions when he described '*new process technologies*' as new 'tools, devices, and knowledge that mediate between inputs and outputs',[14] and changes in '*product technologies*' as 'new products or services', although not in Doessel's restrictive sense.[15]

Brewer did not use the terms 'process' or 'product' in her study of 'technological hardware' used by nurses, but she, nonetheless, categorised new technologies 'into two broad, but crude divisions within the hospital context'[16] that closely parallel Doessel's definitions. Her first category 'consisted of procedures and equipment which attempted to facilitate an existing task, e.g. an electronic thermometer'—what Doessel would define as a *process innovation*. Her second category related to technologies that performed 'tasks which could not previously be done'[17]—a definition which is consistent with Doessel's definition of a *product innovation*. However, the issue of what constitutes a task (or a therapy) that could not previously be done is a moot point, because Brewer[18] exemplified this category with the electronic foetal heart monitor. Was she unaware that foetal heart sounds have been, and still may be, monitored (i.e. listened to and recorded) by nurses using a simple metal foetal stethoscope and written records, or did she interpret the new electronic device as producing a different product/outcome, and hence, it is categorically a product innovation? If it is the latter, then there are subtle differences between Brewer's and Doessel's interpretations on this matter.

Cognisant of these ambiguities, I elected to use Macdonald's conceptualisation of 'technology' as 'the sum of all knowledge …'[19] as my starting definition, and to distinguish the generally acknowledged physical and abstract characteristics of 'technology' using Winner's[20] trichotomous classification (explained below). Other classification schemes, such as Geisler's[21] physical, information, and knowledge perspectives of technology, were considered in the course of my research, but Winner's approach was found to provide the most appropriate framework upon which to build my description and analysis of *surgical technologies*. Winner[22] categorises tools, instruments, machines, and the like, as *apparatus*; skills, methods, and procedures as *techniques*; and rational-productive social arrangements as *organisation*. However, I have substituted the term *artefact* (i.e. any physical 'thing') for *apparatus*, because the current meaning of 'apparatus' is confounded by notions of it being 'a complex appliance' or 'an assemblage of instruments/machinery', whereas *artefact* refers to 'an object made by humans with a view to subsequent use'.[23]

Using Winner's distinctions, the new instruments and related equipment that facilitated the first laparoscopic removal of a gall bladder can be described as *new intra-operative artefacts*, whilst the technology whereby a surgeon employs a new and different way of dissecting tissue without requiring any new artefact, would be referred to as a *new intra-operative technique*. Changes in the configuration of intra-operative artefacts and/or the work arrangements of staff in an operating room when new intra-operative artefacts are adopted would be referred to as *surgical re-organisation*. All three represent *technological change*.

Technical Goals of 'Artefact' Technologies

Zuboff observed that 'throughout most of human history, work has inescapably meant the exertion and often the depletion of the worker's body'.[24] However, since the Industrial Revolution of the late eighteenth century, machines have 'substituted for the human body in many of the processes associated with production and so [have] redefined the limits of production formerly imposed by the body'.[25] In short, the focus has been on mechanical devices applied to primary and secondary industry production that are characterised by their capacity to complete tasks quicker and with more consistent quality than a human worker.

According to Mathews, 'mechanisation has been the principle source of technological change in the workplace over the past century'.[26] Mechanisation *automated* one or more of the processes that had previously been *manu*factured (i.e. made by hand).[27] Until the mid-1900s these machines were predominantly physically operated and controlled by workers.[28] Workers' tasks began to change with the introduction of the mechanically sequenced assembly systems that represented the second phase in the automation of machines—what Mathews refers to as *hard automation.* It was a phase of automation that was implicated in the diminished role of the human worker in the control of machines, and was a predecessor of the computer-controlled automated production. This *programmable automation* phase is characterised by what Zuboff and others refer to as the *informating* of the automation process.[29] This phenomenon is often referred to as 'machine intelligence'.[30] Service industries had been relatively unaffected by the technological changes occurring in production industries until the advent of computer-based information management and communication technologies, exemplified by various office machines such as photocopiers that are now designed to *automate* complex photocopying tasks via their *informating* capacity.[31]

Developments in computing technology have had a great impact on the design and, hence, the functions performed by the diverse biomedical machines that have been adopted by procedural specialists in recent years.[32] However, the actual roles of these machines, and the nature of the human–technology interface, are little understood outside of the operating department.

Expected Organisational Benefits of New 'Artefact' Technology Adoption

It is generally regarded that developments in both *automating* and *informating* technologies have increased the output potential of the average human worker in terms of increased output quantity, the production of new products/services that could otherwise not be produced, and improved product/service quality.[33] In so doing, they have supported the achievement of an organisation's mission and economic objectives.

An organisation's economic objectives are not necessarily dependent on the application of artefact technologies, although it is likely that it will involve them.[34] In many instances, new technologies *substitute* for technologies that are made obsolete by the new. Richardson[35] refers to these as *replacement technologies.* They are adopted because the new technology achieves a desired business objective, such as improved product quality or less per unit cost.[36] However, this is not always the case. New technologies can provide a capacity to do or produce something new whilst not making existing technologies obsolete. The effect is to provide either an *alternative* to an existing technology or a new product that will *supplement* or *complement* an existing technology or product.[37] The present research deliberately selected for study examples of innovations in surgery that represented the replacement, alternative or complementary technology characteristic. It concluded that the dominant reason for new technology adoption in surgery is, typically, enhanced clinical benefit as opposed to the achievement of economic organisational objectives that concern health services administrators.[38]

Since the Industrial Revolution, artefact technologies and their associated technologies have also progressively replaced the relative demand for human labour in production, thereby *displacing human labour* via their automating and/or informating capacities.[39] Even in 1776, Smith[40] acknowledged this potential when he observed that machines 'facilitate and abridge labour, and enable one man to do the work of many'.[41] In 1911, when Taylor promoted his scientific management philosophy on the basis of its capacity to increase the prosperity of workers, he strongly defended scientific management principles against allegations that increased production efficiencies would 'throw men out of work'.[42] However, his argument only held true as long as there was a market for the increased levels of production.[43] More recently, *labour displacement* has not been limited to production industries but extended to service industries such as banking and business services.[44]

Thomas came to the conclusion that 'the idea of technology—and more specifically, the idea of automation as a labour-saving device—can itself become institutionalised',[45] so much so that modern organisations now assume in their new technology adoption decisions that the costs associated with acquiring and operating the new machines will be recouped from the savings in labour costs and increases in productivity, and that enhanced cost-efficiencies will be achieved.[46]

Within health care, the costs and cost–benefits of adopting certain technologies over alternative technologies have been studied extensively in relation to specific technologies and their broader economic impact.[47] Gelijns and Rosenberg, for example, proposed three distinct mechanisms by which technology may contribute to rising health care costs: intensity of use, the introduction of new or modified technologies, and expanded applications of new technologies. They posit that new technologies need not increase health care costs but, rather, 'the way in which a new technology ultimately will affect costs depends on the manner in which it is incorporated into the larger system of medical care—how the profession chooses to use it and to modify it'.[48]

Generally, again, another long-standing assumption has been that when machines replace human labour, the remaining human tasks are simplified and, hence, workers require fewer skills. It is indisputable that from its inception as a management technique, *division of labour* by *task fragmentation* simplified work by comparison with the former structuring of work around the crafts, because employees were no longer required to have as many skills as craftsmen.[49] This was a form of *deskilling*. However, at the same time, workers were expected to become highly skilled (such that they could work faster and at a consistent level of quality output) at those tasks that they did perform. More recently, there has been the growing realisation that much of the human work involved with complex machines, whilst not physically depleting, is mentally demanding work and not necessarily less skilled work.[50]

The skill requirements of a job are determined by many factors. Among them are the knowledge required, 'the difficulty of learning them or executing [the tasks], their simplicity or complexity, whether they are repetitive or not, and whether they are well structured or ill-defined',[51] along with the stability of task characteristics. The present article uses the term *technical complexity* when referring to these characteristics.

The main message of the empirical organisational literature concerning the stability of *task characteristics* is that technological change generally occurs in a planned, system-wide manner affecting entire departments, divisions or organisations. As previously described, the implementation phase of new technology adoption may involve the concurrent operation of old and new technologies. But then, with the exception of post-implementation adjustments in any of the three technological elements (i.e. artefacts, techniques or organisation), the period after implementation is usually stable insofar as there is likely to be a predetermined life cycle of the technologies, during which time work will proceed in a fairly predictable manner.[52]

Research Methods

The design of the research from which the conclusions presented in this article are drawn was a *collective case study*. It employed a mixed methods, mixed methodology approach that combined both inductive and deductive reasoning to draw its conclusions. Its theoretical contributions were derived using the methods and assumptions that are consistent with the *naturalistic paradigm*, which is the dominant paradigm of the research. It also drew some conclusions using the methods and assumptions of *logical positivism* that have important practical implications for the management of operating departments in Australia.

Quantitative data drawn from organisational records, such as registers of surgical procedures and OD staff rosters, combined with an observational time study of direct and indirect labour input to surgical production, led to the conclusion that significant increases occurred in the human labour input to surgical production within ODs during the 10 years to mid-1998.[53]

The data collected to provide an explanation for these increases, discussed herein, were *qualitative* in nature, and derived from formal interviews, informal conversations, and direct observations of people at work within ODs.[54] Comprehensive field notes were kept of the observations and conversations, while all interviews were audio tape-recorded. The average duration of an interview was about an hour.

The qualitative data were analysed using the method of thematic analysis. The dominant themes, which are reflected in the previously cited two research questions, were first identified from the literature represented in the preceding section of this article.

The study sites were five representative, acute hospitals providing surgical services within New South Wales. The hospitals varied according to size, geographic location and public/private ownership. They were coded as Hospital A to Hospital E in the order in which they were confirmed as a research site. Approval to conduct the research was sought and granted by the relevant Ethics in Human Research Committees.

The key informants to the study were individuals whose work roles within ODs involved the use or care of the new intra-operative artefacts (i.e. they were *receivers* of the new intra-operative artefacts[55]) and/or who had the opportunity and/or capacity to contribute to the new intra-operative artefact adoption decision process. Interviews were conducted with a total of 31 operating suite (OS) nurses and seven sterilising department (SD) staff who had at least 10 years experience in their respective practice areas. They were interviewed using an unstructured interview format. Also, 16 experienced surgeons and 13 senior health service managers were interviewed using a semi-structured interview format designed for each category of informant. Informant anonymity was assured by a system of coding. First, an alpha character, X, Y or Z, distinguishing OD staff from health service managers and surgeons, was added to the hospital code, and then three numeric characters were sequentially allocated in the order in which informants in each category were interviewed at each hospital. Hence, the eighth OS nurse interviewed at Hospital B would be identified as BX008.

A range of strategies were employed to ensure the *trustworthiness* of the research process.[56] For example, the tape-recorded interviews were transcribed by an independent text processor, 'member-checking' of interview transcripts[57] was completed before deductive thematic analysis was undertaken by the researcher with the aid of the HyperRESEARCH™ qualitative analysis computer software,[58] and a random sample of 10 interviews were coded by an independent research assistant and the researcher as an inter-coder reliability check.[59] Conclusions were drawn using the principles of *triangulation* whereby multiple sources of evidence converge on a particular fact/finding.[60] For a comprehensive description of the research process and techniques employed to ensure the trustworthiness of the research findings, readers are referred to other articles by the author.[61]

Findings and Discussion

Not Automating but Enabling Surgical Artefacts

In the intra-operative phase of surgical production, technological change has taken the form of either enhancements to established procedures using new intra-operative artefacts in order to improve the process and/or outcome for the patient, or the introduction of altogether new types of procedures that employ innovative intra-operative artefacts. In either case, *automation* is not a technical goal of the innovation itself. Rather, the technical goals of *process innovations* or *product innovations*[62] in surgery are strongly linked to the *clinical* goals, and not to the traditional organisational *self-interested business* goals, such as those associated with strategies aimed at ensuring organisational survival via increased profitability or productivity.[63]

The following description of aspects of the procedure of colonoscopy (i.e. endoscopic examination of the colon) demonstrates the *enabling* characteristics of surgical artefacts. Diverse equipment, peripheral to the colonoscope, make it possible to inflate the colon with air, pump water into it and aspirate fluid from it, supply the 'cold light' that is transmitted via the fibre optics built into the colonoscope to illuminate the colon, and continuously transmit the images onto the television screen. Without such enabling equipment it would be impossible for the proceduralist to perform the colonoscopy or to perform, using additional enabling equipment, any associated procedures such as tissue biopsies, removal of polyps, cauterisation of bleeding vessels, or laser treatment to tumours. For example, when removing polyps, a polypectomy snare inserted down a channel in the colonoscope is connected to an electrical lead that plugs into a diathermy machine, which supplies the electrical current necessary to cauterise the blood vessels to the polyp. The electrical circuit is completed with an electrode being affixed to the patient and its connecting cable is plugged into the diathermy machine. The proceduralist selects the level of electrical current that will be used, and the entire procedure is controlled and completed by him/her.

This description of colonoscopy exemplifies how the main *technical goal* of the diverse enabling equipment observed during the course of the present research is only to *facilitate* the operation of the sophisticated surgical instruments used and controlled by one or more members of the surgical team. I elected to use the term *enabling* to describe this technical goal. *Enabling equipment* is typically electronic, and may possess some algorithm-based 'machine intelligence' that is usually supplied by the types of computing technologies that are associated with 'programmable automation' in production industries.[64] Overall, their built-in intelligence does not perform functions that would otherwise be performed by humans. In other words, with rare exceptions, such as the surgical robot (discussed later), they are not designed to displace human labour or simplify work.[65]

OS nurses were always emphatic when expressing their views on the technical goals of new surgical artefacts. For example, when seeking clarification on a point I asked a nurse, 'so, adopting the new technologies hasn't been driven by trying to replace somebody's job with a machine?' She replied, 'Oh no! I don't see it that way at all!' (Informant DX009). Similarly, an endoscopy nurse responded:

> No. It just adds to our workload … Things have become more difficult and complicated … we needed more staff because most of the stuff we've got needs to be cleaned and looked after. No. It doesn't replace nurses (Informant DX011).

Top managers, on the other hand, appear to have been strongly, but mistakenly, influenced by the mainstream business literature that presents the strategic return-on-investment, techno-economic view of new technology adoption presented in the literature reviewed earlier. For example, a hospital CEO remarked:

> I had the view expressed to me that it's a new technology, it makes life easier, anyone can do it, and because it's new, it's faster, basically that life would be a breeze using it … Maybe it was being equated to industry where technology made things faster (Informant CY002).

One function of the built-in machine intelligence of *enabling equipment* is to provide digital or other functional displays and operator alerts in the events of machine malfunction and/or pre-programmed or operator-programmed safe operating parameters being exceeded. Others are designed to enable a surgeon to exercise greater surgical precision, such as in brain surgery, made possible via computer-aided medical imaging technologies.[66] Even the fairly recent phenomenon of the surgical robot functions under the voice-control of an operator-surgeon. Its function is actually very basic, insofar as it is typically employed in minimally invasive endoscopic procedures to hold an operating 'telescope' steady and change direction in pre-programmed increments on command. Although the surgical robot serves to replace a human operator, the surgical assistant, it was the only example of human labour displacement, or more accurately, role-displacement, resulting from new intra-operative artefact adoption, that came to light in the course of the present research. I have said 'role displacement' because the human labour involved in setting it up, dismantling it, cleaning and maintaining it, is time consuming and the net effect is that of replacing one human factor of surgical production with another at a different phase of production.

The topic of surgical robotics emerged during the course of my interview with a general surgeon (Informant VZ002), who remarked: 'What's blocking people is they think of robots doing laparoscopic gall bladders like we do them now, only with a robot. That's childish'. He went on to say that he could not envisage a future where robotic technologies would not be under the intellectual and/or physical control of a specialist surgeon or radiologist. His comments are in stark contrast to the media portrayal of 'high tech' surgical innovations which tends, by omission, to convey the 'simplification-automation and labour displacement message' of much of the socio-technical literature[67] that goes back to the likes of Adam Smith who observed that 'machines facilitate and abridge labour and enable one man to do the work of many'.[68]

Alternative and Complementary Technologies

An important complicating factor in the new surgical artefact adoption process derives from the fact that new technologies rarely make pre-existing technologies immediately obsolete. This phenomenon is a consequence of various intersecting factors, such as the high acquisition costs of surgical artefacts, diverse organisational constraints, and individual consultant surgeon/proceduralist practice choices.

Whilst immediate *substitution* of a particular surgical technology with a new technology might be desirable for clinical reasons, and does occur, the high cost of a comprehensive replacement of all earlier generation technologies is prohibitive in most instances.[69] Therefore, older surgical technologies typically coexist with newer ones, a situation that often continues for as long as the older instruments and equipment are fully functioning. Sometimes, however, the older technologies quickly become obsolete because of the superiority of the new technology, which proceduralists, as autonomous practitioners,[70] choose to use to the exclusion of older technologies.

However, there are also occasions where the coexistence of two or more generations of surgical technologies is both desirable and deliberate. In some cases, new technologies provide an *alternative* technology[71] that is used when certain clinical criteria are met. In other cases, the new technology is the technology of choice, but its application on some patients needs to be aborted and the proceduralist defaults to using the earlier generation technology. Such is the case for any surgical procedure, such as laparoscopic cholecystectomy, initially embarked upon using minimally invasive techniques and subsequently 'converted' to an open surgical procedure. This has important, and largely unrecognised, consequences for operating department management insofar as it extends the time it takes to complete the surgery on the patient. It also increases the indirect labour because the surgical artefacts for two procedures involving very different technologies must be reprocessed afterwards. For example, within Australia during the final year of the period of the present study, at which time approximately 8,260 conventional cholecystectomies were initially commenced laparoscopically,[72] an estimated 8,810 hours of human labour would have been utilised in accommodating their 'conversion' to open procedures.[73]

Finally, new technologies can provide a capacity to do or produce something new that *supplements* or *complements* an existing technology.[74] One example from the present research is the procedure of hysteroscopy that is now commonly undertaken in conjunction with the long-standing procedure of curettage of the uterus (D&C). The unrecognised human labour consequences of hysteroscopy carried out in conjunction with D&C are more significant than for 'converted' cholecystectomies. The present research concluded that hysteroscopy, as a *complementary technology* to D&C, has increased the total human labour requirement per case by about 75 minutes, representing an increase of 123%.[75] For this procedure alone, this would have amounted to an increased national labour requirement of about 72,205 hours during the final year of the study period when 57,557 hysteroscopies were performed in hospitals throughout Australia.[76]

All of these phenomena—incremental substitution, alternative technologies, and complementary technologies—contribute to the labour intensification of surgical production and add to the complexity of work for *receivers*, particularly OS nurses and SD technical aides whose work is trans-disciplinary.

Frequent, Ad Hoc, Short-lived Changes in Surgical Technologies

An associated aspect of the new technology adoption and diffusion process is the common practice of trialing surgical innovations that may or may not ultimately be adopted into practice. Gelijns and Rosenberg have drawn attention to what they refer to as 'a serious misconception' that the development of a new medical technology ends with its adoption into clinical practice. They highlight that medical devices (such as intra-operative artefacts) are characterised by high levels of incremental change, and that 'actual adoption constitutes only the beginning of an often prolonged process in which important redesigning takes place [by way of] feedback of new information generated by users'.[77] Consequently, many procedural specialists are actively involved with biomedical scientists in the research and development activities that both precede and follow the adoption and diffusion of new surgical technologies.[78] Indeed, 'they develop as they diffuse'.[79] The present research affirms this stance.

New intra-operative artefact adoption is rarely a simple case of choosing and using, and a largely hidden aspect of this process is trialing many new intra-operative artefacts that may or may not end up being adopted. Even when a choice has been made, incorporating the new artefact into practice typically involves incremental adjustments in technique, and possibly the adoption of other artefacts, until the procedural specialist is satisfied with the overall process and its outcome—a process that is repeated when other innovations emerge in one or other procedures across all surgical specialties.

The process whereby the decisions are made to adopt or, in the interim, trial new intra-operative artefacts, is not explored in the present article. Suffice it to say that it is the procedural specialist who decides whether (s)he will trial or adopt any new intra-operative artefact, and that (s)he will rarely continue to use a technology that does not fulfil her/his clinical expectations. The important point, however, is that any process of trialing new intra-operative artefacts represents *technological change* that adds to the complexity of *receivers*' work and contributes to the labour intensification of surgical production.

An OS unit manager explained the frequency with which biomedical companies are seeking to introduce new technologies for trial in her cardiac unit, and explained her response:

> As a manager, I must get calls from some reps on a weekly basis about something new they want to show me. A lot of the surgeons organise for reps to ring me up to arrange to come and show me something new. … if we can see the benefit for the patient from using this particular piece of equipment, we're pretty happy to go with it … We tend not to just trial things willy nilly (Informant DX005).

Receivers of the intra-operative artefacts being trialed must be instructed in how to use, care for, and reprocess them. This can be a time-consuming, challenging process for those concerned, especially when the process might be repeated for any number of artefacts during any given period of time. OS nurses with trans-disciplinary roles appear to be most affected by this practice because, for example, they could be involved in trialing artefacts in several surgical specialities at any given time.

Most significantly, there is no predictable pattern to trialing new intra-operative artefacts. Rather, it occurs in an ad hoc manner *within* individual specialisations (i.e. typically, it is not widespread), and the short time frames associated with most trials means that, unless the artefacts concerned are adopted after the trial period, the sequel to the trial is further technological change.[80] This change might be a return to the former technology or it could involve another trial and, hence, another technological change.

A hospital General Manager observed:

> I don't think anybody predicted the treadmill that you'd get on. That is, you're running just to stand still basically. We're devoting a lot more of our resources to theatre technology and we're just maintaining our technological base (Informant BY001).

Trialing has the effect of adding to the technical complexity of surgical production for the simple reason that all changes in surgical technologies add complexity to the process, at least until the new technology is mastered or discarded. An orthopaedic surgeon explained this process in relation to knee joint replacement surgery:

> Things work in fashions and trends … You'd dabble with the occasional new prosthesis but you'd generally have maybe one prosthesis you'd use for two years or three years and then something else comes along that's a major change which usually you need to move towards. Along the way you might do two or three new brands … It's sort of like comparing a Holden [car] and a Falcon, sometimes you just sort of go for a test drive with the other one to see whether or not you feel comfortable with the way the instrumentation works and the predictability for you to do that procedure (Informant DZ001).

Increase in Volume, Complexity and Specialist Characteristics of New Surgical Artefacts

There has been an accelerating increase, since the late 1980s, in the technical complexity of surgical artefacts and the volume of technically sophisticated surgical artefacts designed for dedicated specialist applications. These phenomena, combined with those discussed in the previous sections, have contributed to both the need for more in-service education and training of *receivers* and a significant increase in the manual labour input to the perioperative phase of surgical production. All these factors have contributed to the labour intensification of surgical production, for which some evidence was provided in the introductory section of this article.

According to OD personnel who have worked in the field for up to 35 years, the speed of change in surgical technologies, particularly during the early 1990s, was greater than anything they had previously experienced. A manager with OD nursing experience since the mid-1960s clearly described some of these issues:

> I would think it must have been around the late 80s. I can remember thinking that you needed a degree in technology or electronics as well as the nursing background that you have, because things changed, and they changed very rapidly. Not only was it changing for the nurses, it was changing for the doctors. They were going through a learning curve the same time as we were … Advances in minimum access surgery in the early 90s had a really big impact. It was reasonably manageable when you had just the Gynaecologist and the Orthopod wanting the TV monitors and so on, but then the Urologists and the general surgeons … They all wanted to do it … I have a long background in theatres, and I know that nothing much had changed for a long time. And then we had this sudden five years of fairly steep curve of changes from the late 80s … When you had to actually go from taking a gall bladder out using a 10 inch incision, to a couple of little stab wounds and a whole lot of equipment, making sure it was all plugged into the right place. Even for the surgeon it was all new. Nobody in the theatre was an expert … I think there have been changes and improvements since 1994, but it hasn't been as huge a change as previously (Informant EY001).

Another experienced OS nurse put it this way:

> When I first came to theatres [21 years ago] everything was fairly simple and the amount of equipment that we used was relatively small whereas now it's just huge … the amount of stuff that's used … Each type of surgery, whether we're talking about laparoscopic gynae work or urology work, it's all changed immensely in 10 years and the technology behind it has changed as well (Informant DX005).

No speciality area of surgery seems to have been untouched by technological changes during this period. For example, concerning stereotactic neurosurgery, one OS nurse remarked, 'there's a lot more instrumentation … [and it's] far more technical than it used to be' (Informant DX003). Eye surgery for the treatment of cataracts is another case in point. Until the late 1980s, the main requirements were an operating microscope and a set of micro-fine surgical instruments. The development of the phaco-emulsifier technology accompanied by changes in intra-ocular lens technology, transformed cataract surgery in the late 1980s. No longer did a relatively long incision need to be made in the eye to remove the cataract-damaged lens. Rather, through a very small incision, an instrument connected to the phaco-emulsifier machine is employed to transmit the shock waves that shatter the damaged lens. The surgeon then aspirates the lens from the eye and inserts a new flexible lens. A nurse provides some insights into the adoption process and the impact of this transformation on her work:

> With the technical side of [the Phaco-emulsifer approach] there was all this equipment to hook up, there was a change of machines, and they were continually, it seemed, trialing and updating the machines. So you'd sort of just learn one technique and one machine and then another one would come and you're adjusting all the time to changes there (Informant DX009).

Interviews with all OS nurses highlighted how increased setting up times for surgery had become a very common characteristic of all surgical specialties, but the impact is most dramatic in those employing minimally invasive technologies. For example:

> Laparoscopic and arthroscopic work is a little frustrating and time consuming. It requires a lot of instruments … and it is a fiddle setting up. Setting up for a normal open operation is quite easy, but with laparoscopic surgery, particularly some of the more complicated ones that we do, it involves a lot of instruments and a lot of setting up (Informant AX001).

However, technological changes have not been limited to minimally invasive technologies. For example, open joint replacement surgery has also undergone substantial, although largely incremental, continuous *artefact* innovation during the 10 years since 1988. This resultant complexity is exemplified in a study conducted during the mid-1990s by Phillips *et al.*[81] which found that there were 41 different prostheses in use in total knee replacement (TKR) procedures. These 41 different prostheses represent a range of alternative intra-operative techniques and prosthesis designs and applications.[82] Whilst a discussion of these clinical issues is out of the scope of the present article, these data serve to highlight the diversity of individual TKR operations and the complex technological factors surrounding even a single type of surgical procedure. Because of this phenomenon, and the very high cost of surgical artefacts, the practice of biomedical companies lending sets of instruments to hospitals for specific surgical procedures has evolved over the years and intensified during the study period. However, the phenomenon has contributed to an increase in the indirect labour input, for example, to total knee replacement by at least 37%.[83] An OS nurse explained:

> In hip and knee replacements, the surgeons here like to use special equipment. People order them in because the equipment is so dear to purchase. They make loan equipment available … all the instrumentation and implants with the set up … But it's very time consuming checking it all in … and we always have two people [do it]. The instruments [arrive] unsterile and they all have to be washed and put through the process and sterilised (Informant AX007).

Technological complexity also derives from the wide variety of *surgical instruments* used now in conjunction with diverse *enabling equipment*, and the fact that both have a propensity to failure or sub-optimal performance intra-operatively. As one nurse remarked:

> Laparoscopically is much more technical instrument-wise than an open cholecystectomy. I think the people outside don't understand the trouble you can get into. If we have a problem with any of the monitors or any of

> the machinery or instruments, that can actually change that whole operation into an open cholecystectomy [which is] a major operation, a longer operation, which is worse for the patient (Informant BX005).

Similarly, another nurse remarked:

> The doctors would say, 'I haven't got a picture [on the monitor], nurse'. So we had to become technicians didn't we? It's a lot of pressure when things break down. Surgeons, for some reason, are rather unforgiving people, and everything has to work … so, 'why doesn't it?' The magic wand doesn't always work either (laugh) (Informant CX002).

The increased technical complexity of intra-operative artefacts also has consequences for perioperative work. The greatest sources of increased perioperative work are the significant increase in manual reprocessing of surgical instruments, the maintenance of enabling equipment, and inventory management activities associated with single-use surgical artefacts used largely in association with minimally invasive technologies. For example, several OS nurses commented specifically about the erroneous perception of top managers that the new sterilising machines eliminated all manual handling aspects of instrument reprocessing, as one nurse remarked concerning the cleaning and sterilisation of a colonoscope:

> It is all manual handling. The 'scope needs to be cleaned. It needs to be rinsed, soaked, the channels cleaned again. The only change here is that it is actually put through the [sterilising machine] … It's just that we don't soak them in [the chemical] gluteraldahyde any more … It's actually created an extra headache because [the sterilising machine] is an extra bit of equipment that needs to be checked [and] extra equipment needs to be ordered to run [it] … and there's problems that occur with [the machine], with filters failing [and so on] … (Informant BX004).

This scenario is pervasive in sterilising departments where the increased technical complexity of intra-operative artefacts has led to an increase in the proportion of *surgical instrument reprocessing* activities that are undertaken *manually* as opposed to being undertaken by machines. This is compounded by the increased number of instruments requiring detailed inspection before they are packaged for sterilisation. Both have contributed to the increases in indirect labour input to surgical production and the need to upskill SD technical aides to deal with the increased technical complexity of their work. All interviews with SD technical aides mentioned these things, as a SD manager explained:

> When the increase [in minimally invasive surgery] started we had great problems with the staff because of training issues and the staff adjustment to that. It's hard. One day you're doing the instruments like … you just open them up, put them in a basket with lots of other instruments, and then send them through the ultrasonic [machine], and the next day somebody says, 'do this laser equipment' or 'here, be a mechanic and pull that apart and put it back together again'. With the minimum access instruments, you wash one at a time and you have to do it by manual handling. You hold the instrument in your hands and count the screws and everything else. There is no putting it through a machine (Informant DX008).

And the changes are not limited to minimally invasive surgical technologies, as another SD technical aide explains:

> Nowadays they do much more joint replacement than they ever did, and the instrumentation … they have 10 boxes with up to 20 trays of instruments altogether. They need to be washed and packed and sterilised, just the same as any other and that's why the workload has drastically increased (Informant DX008).

Conclusion

This article has described the intensification of operating department labour and the increased task complexity of operating department work as two largely unrecognised consequences of technological change in surgery during the 1990s. It has identified and discussed the main four technology-related factors that contributed to these phenomena: the enabling, not automating, characteristic of biomedical equipment and specialist surgical instruments; new intra-operative artefacts rarely displacing pre-existing technologies very quickly; constant, unpredictable technological change; and a dramatic increase in the volume, technical complexity and specialist characteristics of new intra-operative artefacts. These factors and their organisational consequences are inconsistent with the pervasive theme of the techno-economic organisational literature that equates 'new technology' with automation, labour displacement, work simplification, and the economic benefits accruing to an organisation.

Notes and References

1. P. L. Johnstone, 'The process and organisational consequences of new artefact adoption in surgery', PhD thesis, Macquarie University, Sydney, 2001.
2. J. P. Newhouse, 'Has the erosion of the medical marketplace ended?', *Journal of Health Politics, Policy and Law*, 13, 1988, pp. 263–77; S. Folland, A. C. Goodman and M. Stano, *The Economics of Health and Health Care*, MacMillan, New York, 1993; A. Gelijns and N. Rosenberg, 'The dynamics of technological change in medicine', *Health Affairs*, 13, 3, 1994, pp. 28–46; M. Fett, *Technology, Health and Health Care*, Occasional Papers: Health Financing Series, Volume 5, Commonwealth Department of Health and Aged Care, Canberra, Australia, 2000.
3. R. Donato and R. Scotton, 'The Australian health care system', in G. Mooney and R. Scotton (eds), *Economics and Australian Health Policy*, Allen & Unwin, St Leonards, NSW, 1998, pp. 20–39; New South Wales Health, *Summary Table for All AN-DRGs (v3.1), Public and Private Acute Hospitals, New South Wales, 1996–97,* http://www.health.nsw.gov.au/iasd/isc/, 1998 [accessed 13 August 1999].
4. Commonwealth of Australia, *National Hospital Cost Data Collection. Cost Weights for AN-DRG Version 3.1-1997/98. All Hospital-Public Sector*, 1998, Microsoft Excel file provided by Commonwealth Casemix Unit, Canberra, 3 September 1999; CDHSH (Commonwealth Department of Human Services and Health), *Report of the Operating Room Service Weights Study*, Deloitte Touche Tohmatsu, July 1995; C. Aisbett, G. Palmer, L. M. Balnave, V. Hathaway and N. Milis, 'Executive summary', *The Development of Service Weights for the National Casemix Costing Study Using the Australian Revised DRGs Version 4.0, Report to the Commonwealth Department of Health and Family Services,* The Centre for Hospital Management and Information Systems Research, University of New South Wales, Sydney, 1998, pp. 1–7.
5. Johnstone, 2001, *op. cit.*; P. L. Johnstone, 'Do the national operating room service weights reflect the actual human labour requirements of surgical production?', *Proceedings of the 14th Casemix Conference*, Melbourne, 1–4 September 2002.

6. R. Coombs and K. Green, 'Work organisation and product change in the service sector: the case of the UK National Health Service', in S. Wood (ed.), *The Transformation of Work? Skill, Flexibility and the Labour Process*, Unwin Hyman, London, 1989, pp. 279–94 at p. 279; E. Geisler and O. Heller, *Managing Technology in Healthcare*, Kluwer Academic Publishers, Boston, MA, 1996.
7. Gelijns and Rosenberg, *op. cit.*
8. Funk & Wagnalls, Inc., *Funk & Wagnalls New Encylopedia*, USA, 1983.
9. I. B. Brune, 'Historical development of laparoscopic surgery', in I. B. Brune (ed.), *Laparo-Endoscopic Surgery*, 2nd edition, Blackwell Science, Oxford, UK, 1996, pp. 5–12; N. A. Hirsch, *Minimal Access Surgery: An Update*, Australian Institute of Health & Welfare, AGPS, April 1994; J. Perissat, 'Laparoscopic cholecystectomy: the European experience', *The American Journal of Surgery*, 165, April 1993, pp. 444–9.
10. J. Richardson, *Is 8% of GDP Enough: The Future Direction of Australia's Health Care System. Working Paper 2,* National Centre for Health Program Evaluation, West Heidelberg, Victoria, 1990, p. 5.
11. S. Macdonald, 'Technology beyond machines', in S. Macdonald, D. Lamberton and T. Mandeville (eds), *The Trouble with Technology. Explorations in the Process of Technological Change*, Frances Pinter, London, 1983, pp. 26–36 at p. 27.
12. D. P. Doessel, *The Economics of Medical Diagnosis: Technological Change and Health Expenditure*, Avery, Aldershot, UK, 1992.
13. *Ibid*, p. 17.
14. E. Pusić, 'Organisation theory and participation', in F. Heller, E. Pusić, G. Strauss and B. Wilpert (eds), *Organizational Participation. Myth and Reality*, Oxford University Press, Oxford, 1998, pp.65–96 at p. 73.
15. Doessel, *op. cit.*
16. A. Brewer, *Nurses, Nursing and New Technology: Implications of a Dynamic Technological Environment*, Australian Studies in Health Service Administration, No.47, University of New South Wales, Kensington, 1983, p. 13; Doessel, *op. cit.*
17. Brewer, 1983, *op. cit.*, p. 13.
18. A. Brewer, *New Medical Technologies in the Health Sector and Their Labour Market Implications: Final Report*, A study commissioned by the Department of Employment and Industrial Affairs, Canberra, School of Health Administration, University of NSW, Sydney, 1986.
19. Macdonald, *op. cit.*, p. 27.
20. L. Winner, *Autonomous Technologies*, MIT Press, Cambridge, MA, 1977.
21. E. Geisler, 'Multiple-perspectives model of medical technology', *Health Care Management Review*, 24, 3, 1999, pp. 55–63.
22. Winner, *op. cit.*, pp. 8–12.
23. Geisler, *op. cit.*; *The Macquarie Dictionary*, 3rd edition, The Macquarie Library, Macquarie University, NSW, 1997.
24. S. Zuboff, *The Age of the Smart Machine. The Future of Work and Power*, Basic Books, USA, 1988, pp. 22–3.
25. *Ibid*, p. 22; compare with D. Littler, *Technological Development*, Industrial Studies Series, Philip Allan, Oxford, 1988.
26. J. Mathews, *Tools of Change. New Technology and the Democratisation of Work*, Pluto Press, Sydney, 1989, p. 15.
27. C. Cockburn, *Brothers. Male Dominance and Technological Change*, Pluto Press, London, 1983; R. L. Heilbroner, *The Making of Economic Society*, 8th edition, Prentice Hall, Englewood Cliffs, NJ, 1989; L. Hirschhorn, *Beyond Mechanization: Work and Technology in a Postindustrial Age*, MIT Press, Cambridge, MA, 1984.
28. Mathews, *op. cit.*; B. Probert, *Working Life*, Penguin Books, Ringwood, Victoria, 1989.
29. Zuboff, *op. cit.*; Mathews, *op. cit.*; D. F. Noble, *Forces of Production: A Social History of Industrial Automation*, Oxford University Press, New York, 1986; M. Elam, 'Puzzling out the post-Fordist debate: technology, markets and institutions', in A. Amin (ed.), *Post-Fordism. A Reader*, Blackwell, Oxford, 1994, pp. 43–70.

30. Hirschhorn, *op. cit.*; compare with H. Braverman, *Labor and Monopoly Capital. The Degradation of Work in the Twentieth Century*, Monthly Review Press, New York, 1974; Littler, *op. cit.*; P. S. Adler, 'Introduction', in P. S. Adler (ed.), *Technology and the Future of Work*, Oxford University Press, Oxford, England, 1992, pp. 3–14.
31. Cockburn, *op. cit.*
32. Hirsch, *op. cit.*
33. Zuboff, *op. cit.*
34. P. Mathias, 'The machine: icon of industrial growth', in Macdonald *et al.*, *op. cit.*, pp. 11–25.
35. Richardson, 1990, *op. cit.*
36. Zuboff, *op. cit.*
37. Richardson, 1990, *op. cit.*
38. Johnstone, 2001, *op. cit.*
39. Probert, *op. cit.*; J. M. Shafritz and J. S. Ott, *Classics of Organization Theory*, 2nd edition, Brooks/Cole, Pacific Grove, CA, 1987; D. A. Wren, *The Evolution of Management Thought*, 4th edition, John Wiley & Sons, New York, 1994; R. McKenna, *New Management*, Irwin McGraw-Hill, Sydney, 1999.
40. Smith (1776) in A. Skinner (ed.), *Adam Smith. The Wealth of Nations*, Penguin Books, Harmondsworth, Middlesex, England, 1970, p. 46.
41. Compare with J. Wajcman, 'The masculine mystique. A feminist analysis of science and technology', in B. Probert and B. W. Wilson (eds), *Pink Collar Blues. Work, Gender and Technology*, Melbourne University Press, Carlton, Victoria, 1993, pp. 20–40; R. J. Thomas, 'Technological choice and union–management cooperation', *Industrial Relations*, 30, 2, 1991, pp. 167–92; S. Hill, 'Work and technological change in Australia', in J. M. Najman and J. S. Western (eds), *A Sociology of Australian Society: Introductory Readings*, MacMillan, Melbourne, 1988, pp. 239–92; Shafritz and Ott, *op. cit.*
42. F. W. Taylor, *Scientific Management*, Greenwood Press, Westport, CT, 1947 (a reprint of Harper & Brothers Publishers, New York), p. 13.
43. J. A. Merkle, *Management and Ideology: The Legacy of the International Scientific Management Movement*, University of California Press, Berkeley, CA, 1980.
44. R. Markey, *The Trade Union Response to Technological Change in Australia*, Industrial Relations Research Centre Monograph, The University of New South Wales, Sydney, 1983; E. Applebaum, 'New technology and work organisation. The role of gender relations', in Probert and Wilson (eds), *op. cit.*, pp. 60–84; Hill, *op. cit.*
45. R. J. Thomas, *What Machines Can't Do. Politics and Technology in the Industrial Enterprise*, University of California Press, Berkeley, CA, 1994, p. 207.
46. Thomas, 1991, *op. cit.*, p. 184; compare with Zuboff, *op. cit.*; Adler, *op. cit.*; Wajcman, *op. cit.*
47. For example, M. F. Drummond, *Studies in Economic Appraisal in Health Care*, Oxford University Press, Oxford, 1981; J. Richardson, 'Economic assessment of health care: theory and practice', *The Australian Economic Review*, 1st Quarter 1991, pp. 4–21; M. F. Drummond, 'Economic appraisal and health technology: background to the EC project', *Economic Appraisal of Health Technology in the European Community*, Oxford University Press, Oxford, 1987, pp. 3–14; M. Drummond and G. Mooney, 'Assessing the costs and benefits of treatment alternatives', *Essentials of Health Economics*, University of Aberdeen, Aberdeen, 1983, pp. 31–9; A. A. Scitovsky, 'Changes in the costs of treatment of selected illnesses, 1971–1981', *Medical Care*, 23, 1985, pp. 1345–57.
48. Gelijns and Rosenberg, *op. cit.*, pp. 33–4; compare with Fett, *op. cit.*
49. Smith (1776) in Skinner, *op. cit.*
50. Adler, *op. cit.*; Zuboff, *op. cit.*
51. C. Perrow, *Complex Organizations. A Critical Essay*, 2nd edition, Scott Foresman & Co, Glenview, IL, 1979, p. 162; compare with M. Piore and C. Sabel, *The Second Industrial Divide: Prospects for Prosperity*, Basic Books, New York, 1984; J. D. Thompson, *Organizations in Action. Social Science Bases of Administrative Theory*, McGraw-Hill, New York, 1967; J. Woodward, *Industrial Organisation. Theory and Practice*, 2nd edition, Oxford University Press, Oxford, England, 1980; J. Galbraith, *Designing Complex Organizations*, Addison Wesley, Reading, MA, 1973.

52. C. J. Haddad, *Managing Technological Changes. A Strategic Partnership Approach*, Sage, London, 2002; D. Buchanan and D. Boddy, *The Expertise of the Change Agent. Public Performance and Backstage Activity*, Prentice Hall, New York, 1992.
53. Johnstone, 2001, *op. cit.*; Johnstone, 2002, *op. cit.*
54. D. A. Erlandson, E. L. Harris, B. L. Skipper and S. D. Allen, *Doing Naturalistic Enquiry. A Guide to Methods*, Sage Publications, Newbury Park, CA, 1993; R. E. Stake, *The Art of Case Study Research*, Sage, Thousand Oaks, CA, 1995.
55. P. L. Johnstone, 'Defining surgical technologies and the process relationships between them', *Journal of Advanced Perioperative Care*, 1, 3, April 2003, pp. 69–76.
56. Y. S. Lincoln and E. G. Guba, *Naturalistic Inquiry*, Sage, Beverly Hills, CA, 1985; E. G. Guba and Y. S. Lincoln, 'Do inquiry paradigms imply inquiry methodologies?', in D. M. Fetterman (ed.), *Qualitative Approaches to Evaluation in Education. The Silent Scientific Revolution,* Praeger, New York, 1988, pp. 89–115.
57. Stake, *op. cit.*
58. Research Ware, Inc., *HyperRESEARCH(: A Content Analysis Tool for the Qualitative Researcher*, Research Ware, Randolf, MA, 1997.
59. Lincoln and Guba, *op. cit.*; Erlandson *et al.*, *op. cit.*; B. Dick, 'Sources of rigour in action research addressing the issues of trustworthiness and credibility', unpublished paper presented at the *Association for Qualitative Research Conference*, Melbourne, 6–10 July 1999.
60. R. K. Yin, *Case Study Research. Design and Methods*, 2nd edition, Sage, Newbury Park, 1994, p. 93.
61. Johnstone, 2003, *op. cit.* P. L. Johnstone, 'Mixed methods, mixed methodology health services research in practice', *Qualitative Health Research*, 14, 2, February 2004, pp. 259–71.
62. Doessel, *op. cit.*
63. Mills (1871) in K. W. Kapp and L. L. Kapp (eds), *History of Economic Thought: A Book of Readings*, Barnes & Noble, New York, 1949.
64. Mathews, *op. cit.*
65. Compare with Zuboff, *op. cit.*; Probert, *op. cit.*; Thomas, 1994, *op. cit.*
66. J. Wadley, N. Dorward, N. Kitchen and D. Thomas, 'Pre-operative planning and intra-operative guidance in modern neurosurgery: a review of 300 cases', *Annals of the Royal College of Surgeons of England*, 81, 4, 1999, pp. 217–25; H. Visarius, 'Man–machine interfaces in computer assisted surgery', *Computer Aided Surgery*, 2, 2, 1997, pp. 102–7.
67. For example, *Under the Knife,* 12 April 2001; Braverman, *op. cit.*; Littler, *op. cit.*; Adler, *op. cit.*; Hirschhorn, *op. cit.*
68. Smith (1776) in Skinner, *op. cit.*, p. 46.
69. Richardson, 1990, *op. cit.*
70. G. Mooney, 'Health economics and health policy', in Mooney and Scotton (eds), *op. cit.*, pp. 1–19.
71. Richardson, 1990, *op. cit.*
72. CDHAC (Commonwealth Department of Health and Aged Care), *Casemix Overview*, wysiwyg://MAIN.2/http://www.health.gov.au/casemix/, 1999 [Accessed 13 August 1999].
73. Johnstone, 2001, *op. cit.*
74. Richardson, 1990, *op. cit.*
75. Johnstone, 2001, *op. cit.*
76. CDHAC, *op. cit.*
77. Gelijns and Rosenberg, *op. cit.*, p. 31.
78. Compare with Geisler, *op. cit.*
79. Geisler and Heller, *op. cit.*, p. 134.
80. Compare with Gelijns and Rosenberg, *op. cit.* and Geisler and Heller, *op. cit.*
81. A. M. Phillips, N. J. Goddard and J. E. Tomlinson, 'Current techniques in total knee replacement: results of a national survey', *Annals of the Royal College of Surgeons of England*, 78, 6, 1996, pp. 515–20.
82. R. S. Laskin, 'Management of the patella during revision total knee replacement arthroplasty', *Orthopedic Clinics of North America*, 29, 2, 1998, pp. 355–60; J. A. Rand, 'Modular augments in revision total knee arthroplasty', *The Orthopedic Clinics of North America*, 29, 2, 1998, pp. 347–53;

C. H. Rorabeck and P. N. Smith, 'Results of revision total knee arthroplasty in the face of significant bone deficiency', *The Orthopedic Clinics of North America*, 29, 2, 1998, pp. 361–70; T. P. Sculco and J. C. Choi, 'The role and results of bone grafting in revision total knee replacement', *The Orthopedic Clinics of North America*, 29, 2, 1998, pp. 339–46.

83. Johnstone, 2001, *op. cit.*, p. 191.