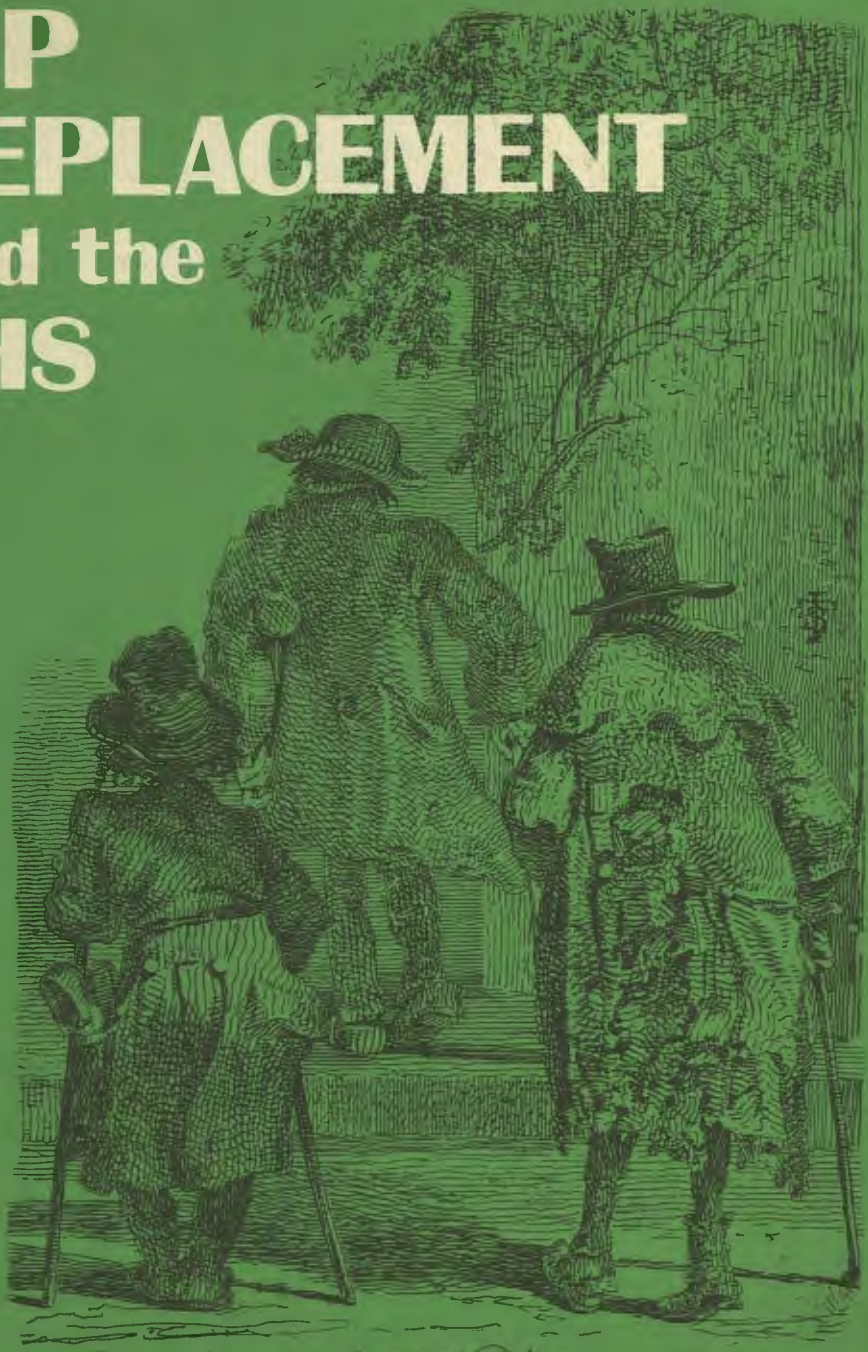
HIP REPLACEMENT and the NHS



HIP REPLACEMENT
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Introduction

Of all forms of joint replacement operation, that for hips represents the most outstanding innovation. It is perhaps the major post-war surgical development and the key example of a technique which can radically improve quality of life at an acceptably low cost.

The main indications are osteoarthritis (osteoarthrosis) and to a lesser extent rheumatoid arthritis. Since its introduction into common use in the 1960s total hip replacement has given approaching 200,000 people in Britain relief from the chronic pain and disability caused by these conditions. With the exception of abortion no other surgical procedure has increased in number so rapidly over the course of the seventies. In 1978, NHS hospitals in England and Wales provided an estimated 15,300[1] total hip replacements (or closely related partial hip replacements) for these diagnoses alone at the cost of some £18 million (1981 prices).

It is upon these, usually elective, operations that this paper concentrates attention,[2] focusing on issues of waiting time, criteria of acceptance for surgery and organisation of surgical resources. It also highlights the poverty of information available to clinicians and administrators for evaluating the services they provide.

The delivery of joint replacement, and in particular hip replacement, may be seen as an important indicator of the performance of the NHS generally. Much attention has been given recently to long waiting times. In-patient statistics, though 3 years out of date, show that average time on waiting lists was greater for elective arthroplasty than for any other operation, with 19 per cent of recipients in 1978 having waited one year or more. The equivalent figure for all surgery was six per cent. A partial explanation for this poor state of affairs has been pressure on orthopaedic resources from an increased incidence of fractured femurs among elderly people.

But for two reasons the prospects for the future may be considerably brighter than is sometimes feared. First, the rate of hip replacement may now be approaching a peak in some regions, even at quite low threshold levels of suitability for surgery. Certainly, data presented below seriously challenge the commonly

1 All total hip replacements, including those for fractured femur and other causes, amounted to an estimated 18,000, making it probably the 6th most significant operation in terms of bed-days.

2 Hip replacement for fractured neck of femur and the closely related femoral endoprosthesis, or partial replacement, are entirely excluded from consideration. These are usually emergency operations and as such are given priority, even though the prognosis for the population involved, most of whom are elderly women, is poor. An estimated 2,500 such total hip replacements were recorded in NHS hospitals in England and Wales in 1978 as were a further 7,800 femoral endoprotheses.

held view that any feasible level of resources is capable of saturation by demand for replacement. Second, the very fact that throughput is so variable from region to region indicates that it could be substantially raised in many cases. The recent report of the DHSS Working Party on Orthopaedic Services confirms the potential for increased services within existing resources and goes on to suggest certain basic management techniques which could help to realise it. Clearly, much depends on the existence of conditions favouring a committment by consultants and others to effective management of resources under their control.

The second most frequent replacement operation is arthroplasty of the knee. Approaching 3,000 were carried out in NHS hospitals in England and Wales in 1978. Fears have been expressed that because the prevalence of arthritic knees is considerably greater than arthritic hips, knee replacements may in the future impose even greater pressures on NHS resources. However, knee replacement is technically more difficult and the risk of failure is higher. In the absence of a major breakthrough, therefore, there is no immediate prospect that knees will 'take off' in the same way as hips did in the sixties and seventies. Nor is there any immediate likelihood of a burgeoning skeletal repair service for shoulders, ankles, wrists, finger joints and elbows, all of which have been successfully replaced in specialist centres.

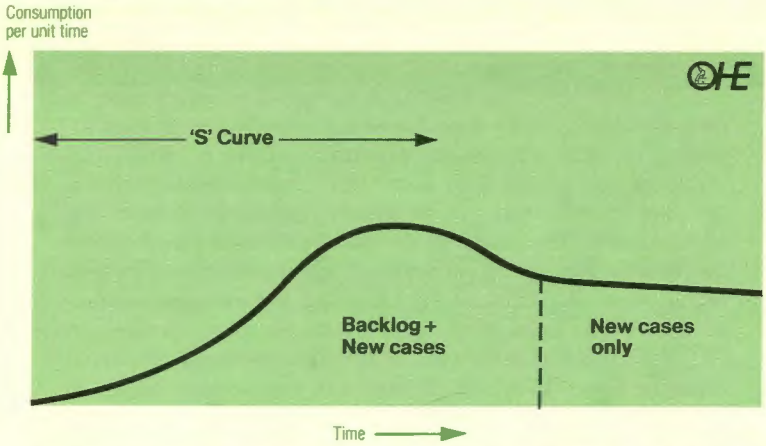
Throughput and potential demand

The following section examines, with limited data, the question 'how does the number of hip replacements performed in recent years compare with the number of persons in the community who could benefit from such surgery ?' It does so by taking the largest single component of workload, replacements for osteoarthritis, and estimating the maximum possible demand at given threshold levels of suitability for surgery.[3]

This question is of particular relevance because of the assumption made by many authors, for example Morris (1975), that potential demand (at undefined criteria of suitability) is large enough to saturate any feasible level of NHS resource provision. Yet apart from simple extrapolation of past trends there is no firm basis for this belief. On the contrary, this paper reaches a tentative conclusion that, in some NHS regions at least, the annual number of operations may recently have been about equal to, or even in

3 For the purposes of this section elective replacement of hips affected by rheumatoid arthritis is excluded. The results tend not to be so satisfactory as they are for osteoarthritis.

Figure 1 *Diffusion of an innovation given a 'stock' of 'old' demand and a 'flow' of 'new' demand*



excess of, new cases reaching a relatively low threshold of suitability each year.[4]

A valuable model of the diffusion of innovation, in any field of activity, is illustrated in Figure 1. It describes an 'S' curve in which slow initial uptake is followed by a period of rapid growth and then a plateau as potential demand is satisfied. For a highly effective innovation like hip replacement, where there is a backlog to be dealt with, a peak may occur some time after the technique's introduction, followed by a decrease to a plateau level representing the flow of new demand. This is the pattern that was observed, for example, when spectacles and dentures were first made available free under the NHS.

If it were found that the number of hip replacements presently being performed were in excess of the incidence of suitable new cases in the population this would imply that the procedure is at or near the peak of its diffusion curve and a decline in numbers could be expected in the short to medium term as the backlog is cleared. If, on the other hand, throughput were found to be lower than the flow of new cases thought likely to benefit this would imply an unknown combination of uncleared backlog and unsatisfied new cases.

The balance of potential demand and throughput it important for two major reasons. First, hip replacement is now the most frequent elective orthopaedic operation and likely future trends in numbers performed are clearly relevant to the case for and against the lobby that has recently developed for more NHS resources to be switched to the speciality of orthopaedic surgery.

4 For knees, replacement technology is substantially less effective, leading to restrictive criteria of suitability for surgery. Little can yet be said with confidence about how numbers of operations on this joint are likely to develop in the future.

Recording Hip Replacements

Before 1967 all arthroplasties were recorded in the Hospital In-patient Enquiry under 'Joint Reconstruction Including Arthroplasty'. No national information specific to hips, therefore, is available before that time. In 1967 the first revision of OPCS operation codes introduced the classifications 'Arthroplasty of the Hip with Prosthetic Device' (810) and 'Arthroplasty of the Hip n.e.c.' (811). Arthroplasty with a prosthetic device was not, however, equivalent to 'total hip replacement'. The latter, as devised by Charnley and others specifically for the treatment of osteoarthrosis, involves replacement of both the femoral and the acetabular components of the joint. 'Arthroplasty with prosthetic device', on the other hand, included femoral endoprostheses, or partial replacements, in which a femoral component alone is inserted. This type of operation is mainly used for fracture of the neck of femur, especially for cases of non-union. (It is also still occasionally used for osteoarthrosis.)

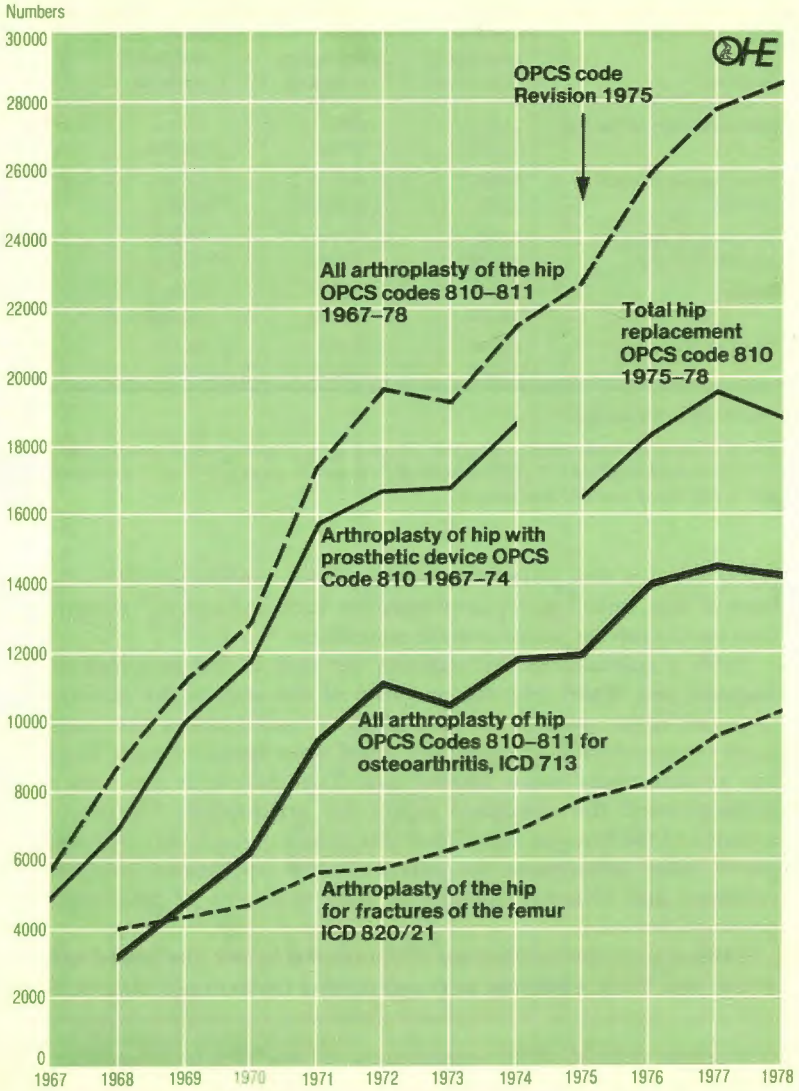
In 1975 a major revision of the OPCS operation codes took place. 'Arthroplasty of the Hip with Prosthetic Device' (810) was replaced with 'Total Hip Replacement' (810). It was anticipated that this would shift partial replacements for fracture into 'Arthroplasty of the Hip n.e.c.'. After a delay while coding clerks adapted themselves to the new information requirements of the revision, the switch-over did take place. It is probable that by 1978 most if not all partial replacements had been removed from 'Total Hip Replacement' (810) into the sweep-up code 811 (Webb 1981).

Second, the extent to which potential demand is already being satisfied can shed some light on the more fundamental issue of the priority that the NHS should give to doing more hip replacements. The key questions that have to be answered here are those relating to the marginal net benefit from additional operations. The closer potential demand is to being fully satisfied the lower the marginal benefits are likely to be.

Throughput

The numbers of hip arthroplasties undertaken in NHS hospitals in England and Wales from 1967 to 1978 are set out in Figure 2. Trends require some explanation (see Box) because of classification changes and because of anomalies in HIPE codes which have resulted in inflated estimates for one particular subset, total hip replacements, being quoted in the past. The latter has been due to the inclusion of partial hip replacements mainly undertaken for non-union of fracture. The position has been elucidated by Webb

Figure 2 *Estimated number of arthroplasties of the hip undertaken in NHS hospitals in England and Wales 1967–1978*



OPCS operation codes

810 = 'Total hip replacement' from 1975 to date and 'Arthroplasty of the hip with prosthetic device' from 1967–1974.

811 = 'Other arthroplasty of the hip, not elsewhere classified' from 1967 to date.

ICD numbers

713 = 'Osteoarthritis'

820/21 = 'Fracture of femur'

Source HIPE various years

Table 1 *Hip arthroplasty. Estimated numbers performed in NHS hospitals, England and Wales 1978*

Diagnosis	*Code 810 Total Hip Replacement*	*Code 811 Other arthroplasty of hip n.e.c.*	*Codes 810 and 811 combined*
Osteoarthrosis of the hip ICD 713	13,270 (70.6%)	930 (9.5%)	14,200 (49.7%)
Rheumatoid arthritis ICD 712	1,050 (5.6%)	80* (0.8%)	1,130 (4.0%)
Fractures of femur ICD 820/821	2,480 (12.1%)	7,770 (79.3%)	10,230 (35.8%)
Other	2,010 (10.7%)	1,000 (10.3%)	3,010 (10.5%)
Total all diagnoses	18,790 (100%)	9,700 (100%)	28,570 (100%)

*Based on small sample.

Source Table D 'Additional'. HIPE 1978. Derived by multiplication of sample numbers by multiplying factor for orthopaedic and traumatic surgery (= No of cases from SH3 form/No of cases in HIPE sample).

(1981) and it is now possible to estimate with confidence the numbers of NHS total hip replacements for each indication,[5] though data on the private sector remain unavailable.[6]

Table 1 summarises the statistics for 1978 in NHS hospitals in England and Wales. For the purposes of this section the statistic required is the number of operations recorded under the diagnosis osteoarthrosis. Thirteen thousand three hundred such 'total hip replacements' were carried out. Together with 900 'other arthroplasties' the combined figure for arthroplasty for osteoarthritis of the hip was 14,200. It is this number which may be compared (after adjustment for private sector operations and for revisions and bilateral operations) with estimates of maximum potential demand.

Table 2 gives the breakdown of operations by sex and broad age group and Table 3 sets out rates per million resident population in

5 It appears that a significant residual number of 'true' total replacements are being carried out for fractures. Thirteen per cent of code 810 were classed under the diagnosis of fracture in 1978 (Table 1). This compares with a figure of 3·9 per cent found by Kay (1981) in a study of 1,085 recipients of total hip replacements in 32 centres in England and Wales in 1975. Other percentages reported in the literature are usually smaller.

6 In 1980 BUPA – with 70 per cent of the private insurance market – paid claims in respect of 700 hip replacements. In addition to operations paid for by other insurance carriers it is believed that substantial numbers of older people, relatively few of whom are covered by private insurance, pay out of their own pockets or are financially aided by their families.

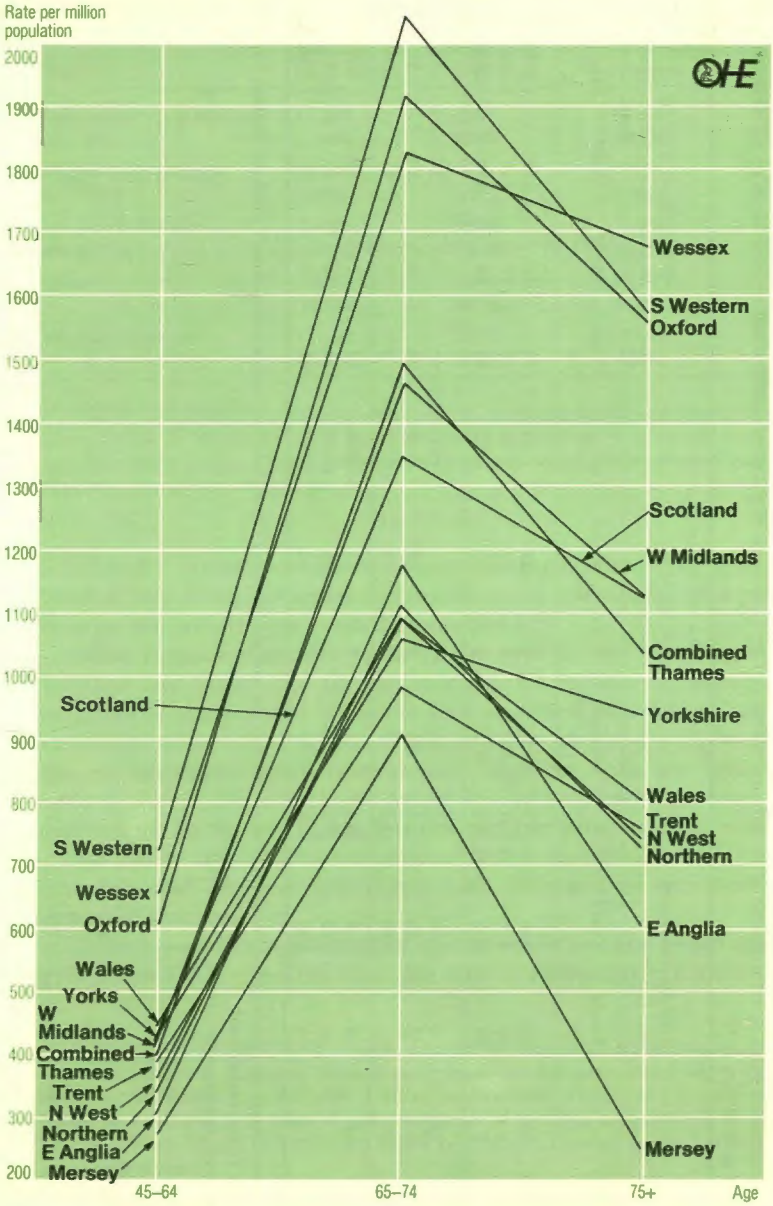
Table 2 *Estimated rates of arthroplasty of the hip operations per million home population carried out in NHS hospitals by diagnosis, age and sex. England and Wales 1978*

		Total hip replacement OPCS Code 810				*Other arthroplasty of the hip n.e.c. OPCS Code 811*				*All arthroplasty of the hip OPCS Codes 810 and 811 combined*			
		15–44	*45–64*	*65+*	*All ages 15+*	*15–44*	*45–64*	*65+*	*All ages 15+*	*15–44*	*45–64*	*65+*	*All ages 15+*
Osteoarthrosis	M	12	386	1,019	278	0	30	81	22	12	416	1,200	300
ICD 713	F	22	413	1,257	407	4	27	77	27	26	440	1,324	434
	P	17	400	1,163	346	2	29	79	24	19	429	1,242	370
Rheumatoid	M	4	30	33	17	—	—	—	—	4	30	33	17
Arthritis	F	6	50	89	37	2	9	2	4	8	59	91	41
ICD 712	P	5	40	67	27	1	5	1	2	6	45	68	29
Fracture of	M	0	9	114	21	1	25	290	52	1	34	404	73
the femur	F	0	36	423	104	1	63	1,449	340	1	99	1,872	444
ICD 820/21	P	0	23	304	64	1	45	1,001	202	1	68	1,305	266

Note Operation/diagnosis combinations with less than 5 cases in the sample for all age groups for a given sex (less than 2 cases per million population) are not available from Table D additional.

Source HIPE Table D additional 1978.

Figure 3 *Arthroplasty of the hip (operation codes 810 and 811 combined) for osteoarthritis (ICD 713). Estimated* rates per million population by region of residence and age. 1978*



*Traumatic and orthopaedic surgery national multiplying factor used.

Source HIPE 1978

Table 3 *Arthroplasty of the hip (OPCS codes 810 and 811) for osteoarthritis (ICD Code 713) by region of residence.*

Region	*Rate per million population*
Northern	224
Yorkshire	252
Trent	231
E Anglia	209
Combined Thames	308
Wessex	423
Oxford	368
S Western	448
W Midlands	284
Mersey	164
N Western	242
Wales	258
England & Wales	289
Scotland	277

Source HIPE 1978. Scottish Hospital In-Patient Statistics.

each region. For osteoarthritis operation rates increase with age, reach their peak among 65–74 year olds and drop again thereafter. Figure 3 illustrates age specific rates by region of residence. The usual pattern of wide variation in NHS provision applies. For the 75 + age group there are particularly marked disparities, the highest and lowest regions differing by a factor of 7 to 1. As frequently found it is the poorer regions of the midlands and the north that report the lowest operation rates.

Potential demand for hip replacement

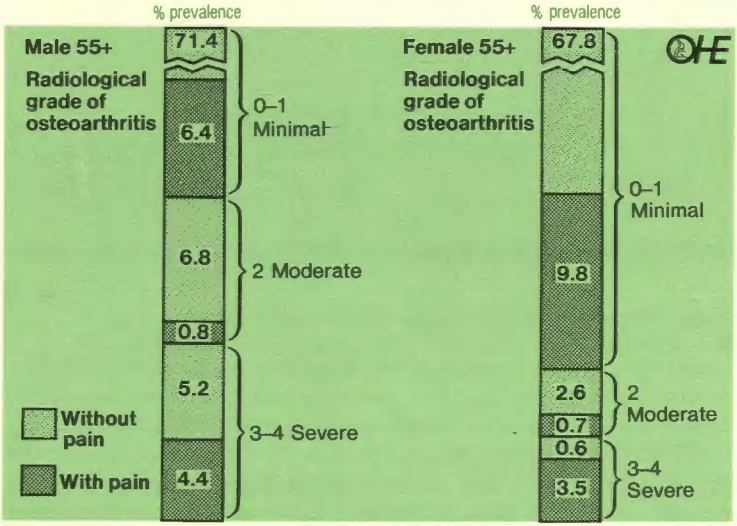
Osteoarthrosis occurs less frequently at the hip than it does at other sites, like the fingers and the knee (Lawrence, Bremner and Bier 1966, Allander 1974). But when it does occur it can be particularly disabling. Figures 4a–f reproduce data on prevalence of osteoarthritis from a number of surveys in Europe and America. They include, where available, information on the numbers of cases upon which prevalence estimates are based. They are mostly small, and errors are correspondingly large. The object of this subsection is to see whether any conclusion can be drawn from comparing these data with the number of operations carried out for this diagnosis under the NHS.

It is immediately apparent from inspection of Figures 4a–f that the variety of diagnostic criteria used in the surveys and the differences in age structures of the populations concerned do not facilitate comparisons. Nor, except in one case, are the diagnostic criteria directly related to suitability for surgery. Radiological diagnosis, being reasonably reproducible, is most frequently used for epidemiological purposes but it is inadequate for estimating the potential demand for hip replacement since X-ray evidence of degeneration is poorly correlated with pain, the main indication

Figure 4 *Prevalence of osteoarthrosis of the hip found in certain surveys, according to criteria chosen*

a) Lawrence, Bremner and Bier 1966

% prevalence osteoarthrosis of the hip. Age 55 + excluding 'probable' or 'definite' rheumatoid arthritis.



Population: Sample of 251 males and 316 females in Leigh and Wensleydale. Aged 55+. Late 1950s.

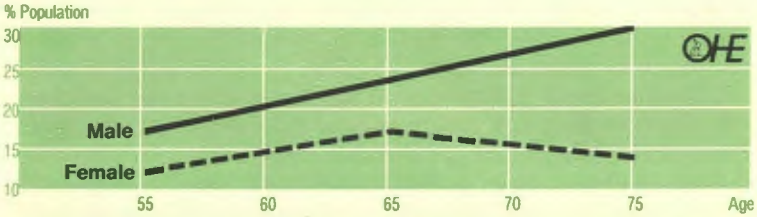
Diagnostic Criteria: Subjects graded 0–4 osteoarthrosis on the basis of X-rays. Co-existing rheumatoid arthritis diagnosed on the basis of history, radiological and serological evidence.

Pain includes past and present distress amongst all grades of severity reported on prompting during examination.

Source Lawrence J S, Bremner J H and Bier F (1966). Ostoearthrosis: prevalence in the population and relationship between symptoms and X-ray changes. *Ann Rheum Dis* (1966), 25, 1.

b) Kellgren 1961

% prevalence osteoarthrosis of the hip by age and sex.



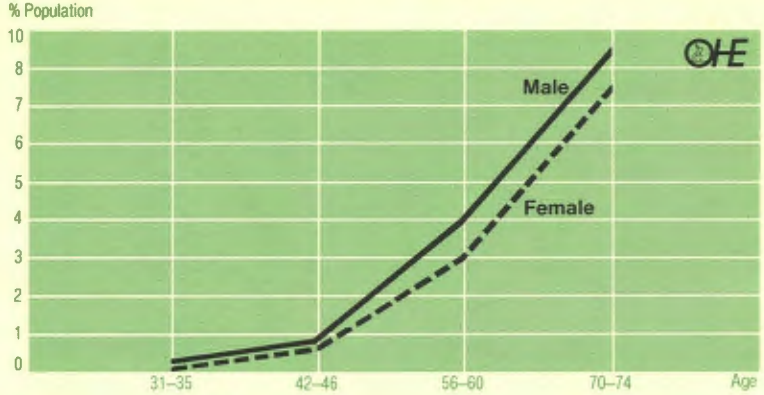
Population: Sample of persons examined in a mobile examination centre in Leigh.

Diagnostic Criteria: Radiological demonstration of osteophytic outgrowths or subchondral bone sclerosis. No measurement made of pain or disability.

Source Kellgren J H (1961). Osteoarthrosis in Patients and Populations, *BMJ*, 2, 1:1–6.

c) Allander 1974

% prevalence arthrosis of the hip by age and sex, Sweden



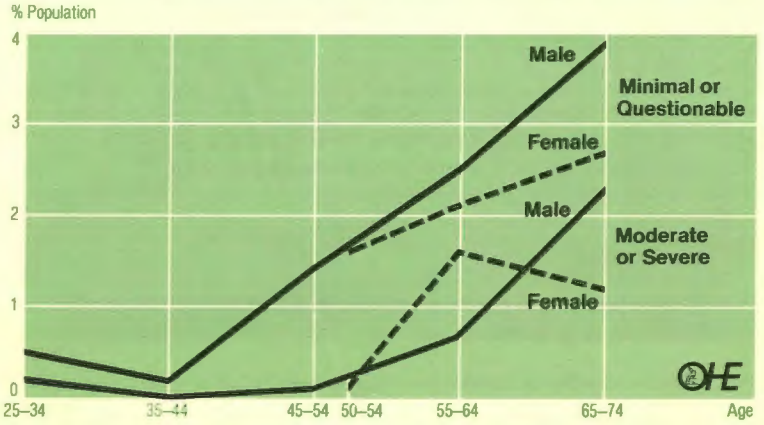
Population: Sample of 4,195 persons aged 31 to 74 and resident in Stockholm during 1965–68.

Diagnostic Criteria: Clinical examination only. Arthrosis of hip defined as definite restriction of hip joint rotation with the patient in the sitting position, together with present or previous joint pain. No X-ray examination.

Source Allander E (1974). Prevalence, incidence and remission rates of some common rheumatic diseases or syndromes. *Scand J Rheumatology*, 3: 145–53.

d) Hanes 1971–75

% prevalence of osteoarthrosis of the hip by severity and by age and sex USA



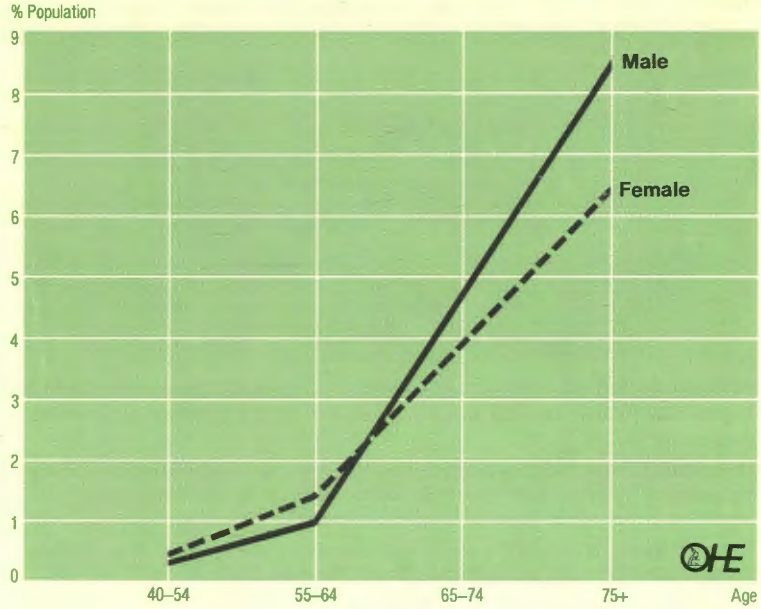
Population: Sample of the USA population surveyed for the American National Health Survey, early 1970s.

Diagnostic Criteria: Assessment from X-ray films of hips. The overall grade was a subjective synthesis of several items. No measurement of pain or disability.

Source Basic data on arthritis of knee, hip and joints in adults from 27–74 years, *DHEW* publication 1979, II: 312.

e) Danielsson 1966

% prevalence primary coxarthrosis of the hip by age and sex, Sweden



Population: 13,903 persons resident in Malmo, Sweden upon whom roentgenography of the colon had been performed and found to be normal, ie, a sample of patients who had consulted and who had been investigated for a condition other than arthrosis. Early 1960s.

Diagnostic Criteria: Structural and/or joint space changes from roentgenography. Presence of osteophytes alone insufficient. Coxarthrosis secondary to known hip disease excluded from rates shown. Inclusion of those increases the total numbers diagnosed from 91 to 108. No measurement of pain or disability.

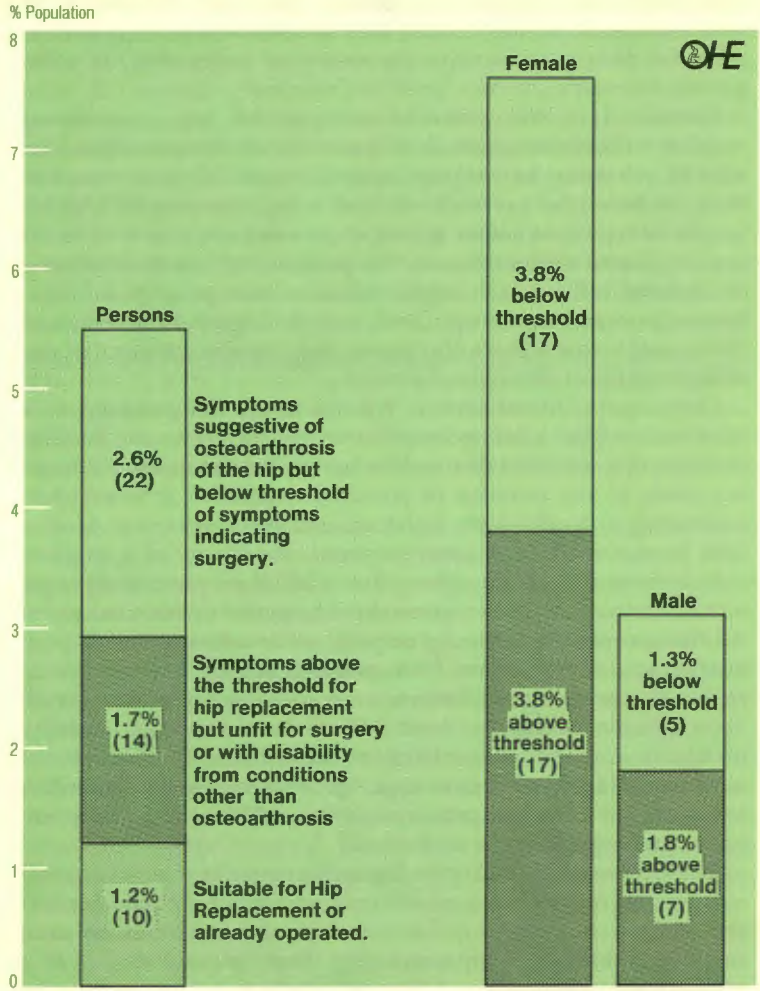
The number of cases on which prevalence estimated was as follows:

	M	*F*		*M*	*F*
40–45	2	3	65–74	21	19
55–64	5	7	75+	20	14

Source Danielsson L (1966). Incidence of osteoarthrosis of the hip (coxarthrosis), *Clin orthop and rel res*, 45: 65–72.

f) Wilcock 1979

Prevalence of osteoarthrosis 'requiring' total hip replacement among persons aged 65+, Oxfordshire.



Population: Sample of 828 persons aged 65+ resident in Oxfordshire in the mid 1970s.

Diagnostic Criteria: Index of daily activities and hip function index (including pain) above a threshold level based on the *least* symptoms or disabilty found among a sample of 50 patients awaiting hip replacement. Persons with rheumatoid arthritis excluded from rates shown.

Number of cases on which prevalence estimated given in brackets in figure.

Source Wilcock G K (1979). The prevalence of osteoarthrosis of the hip requiring total hip replacement in the elderly. *International Journal of Epidemiology*, 8, 3, 247–50.

for surgery.[7] Evidence of hip damage is found more frequently in men than women; but for any given level of radiologically defined arthritis, women are more likely to be symptomatic than men.[8] Wilcock's findings (Figure 4f) indicate that when the nature of symptoms is taken into account, for example through responses to a hip function questionnaire, the excess of males switches to an excess of females.

Estimation of the potential demand for hip replacement requires information on each of a number of characteristics relevant to suitability for surgery. Apart from radiological measures these include: the presence of co-existing rheumatoid arthritis (results of hip replacement among these cases are poorer than for uncomplicated osteoarthrosis); the presence of other co-existing disease, or frailty, which might contra-indicate surgery; information on pain and hip function such as to distinguish between those above and below a given threshold; and a similar measure of disability capable of alleviation by surgery.

Only one published survey, Wilcock (1979), has gathered such information from a defined population specifically for the purpose of estimating potential demand for hip replacement. Since it is the key study in any estimate of potential demand it is worthwhile examining it closely. Eight hundred and thirty-eight over 65 year olds from Oxfordshire were surveyed, consisting of a random sample from a market town together with all people over 65 registered with one of the two general practitioners in a second town. All those reporting difficulty or pain with walking possibly attributable to arthritis, either from previous health screening or in replies to a postal questionnaire, were visited at home. So were all non-respondents together with half of those reporting mobility problems apparently unrelated to arthritis and a sample of negatives. Medical records of the GP group were also scrutinised. A response rate of 99 per cent was achieved. The sample excluded, however, people living in institutions.

The criteria of suitability for hip replacement involved two scoring systems, one an index of ability to perform daily activities and the other a composite hip function including questions on pain, mobility and range of hip movement. Each test was applied to a group of 50 patients selected from waiting lists in the area in order to obtain the least symptoms or disability among people already

7 Thus Lawrence, Bremner and Bier, in their survey of a Yorkshire population in the 1950s (Figure 4a), found that 17·2 per cent of males and 6·3 per cent of females aged 55 and over had radiological evidence of intermediate or severe degeneration of the hip joint due to osteoarthrosis. But only 5·2 per cent and 4·2 per cent of them respectively reported present or past hip pain.

8 It is noteworthy that in all of the surveys which were based on radiological criteria female prevalence rates were lower than male rates, whereas Table 2 shows that operation rates were higher for females at all ages.

accepted for surgery. Thus the threshold of suitability chosen was the lowest consistent with local clinical practice.[9]

Excluding those with previously diagnosed rheumatoid arthritis, 46 persons (34 women and 12 men) were identified as having symptoms suggestive of osteoarthrosis of the hip. The resulting prevalence rate of 5.5 per cent among people over 65 is of the same order as Lawrence, Bremner and Biers' rate of 4.7 per cent among people over 55 (reporting pain and with radiological evidence of intermediate or severe osteoarthritis). But 22 subjects (17 women and 5 men) did not reach the threshold level of symptoms and disability. This gives what may be termed a 'reserve prevalence rate' of 2.6 per cent representing potential implantees should clinical criteria of suitability for operation become less restrictive.

The other 24 (17 women and 7 men) were above the threshold or had already received a hip operation, representing a prevalence of 2.9 per cent. But not all were judged suitable for hip replacement. A further 14 were excluded, either as being unfit (11), as having disability from other conditions (3) or because they improved on medical treatment (2). These exclusions reduced the prevalence of 'operable' osteoarthrosis to 10 persons, equivalent to a prevalence of 1.2 per cent.

Table 4 represents an attempt to link the patchy prevalence data in Figures 4a–4f with the hard information on provision of total hip replacements from Table 1. The object is to see how provision relates to potential demand from new cases of osteoarthrosis. The flow of new cases (incidence) in each age group can be roughly estimated from age specific prevalence on the assumptions: a) that the prevalence of osteoarthrosis, operated or otherwise, is in an approximately steady state within each age group in an approximately stable population structure; b) that mortality rates among people with osteoarthrosis are approximately equal to those for the general population; c) that remission rates for operable osteoarthrosis are minimal. Given these simplifying assumptions the annual flow of new cases implied by the studies of Wilcock in Oxfordshire, Figure 4f, and Danielsson in Sweden, Figure 4e, can be calculated.[10]

Taking Wilcock's lowest prevalence rate, representing those with symptoms in excess of his minimum threshold level and at the same time fit for surgery, the implied flow of new cases among

9 Since hip replacement rates in Oxford (by region of treatment) in 1978 were 36 per cent higher than the average for England and Wales as a whole, and median waiting time 19 per cent lower it is likely that the criteria used were relatively unrestrictive in comparison with other regions.

10 These two surveys are the only ones where data are presented in usable form, but the prevalence levels indicated by Wilcock among over 65s are broadly confirmed, after taking different diagnostic criteria into account, by Lawrence, Bremner and Biers' data, Figure 4a, while the overall and age specific prevalence rates reported by Danielsson are paralleled by those of Allander, Figure 4c.

Table 4

Study	*Diagnostic criteria for osteoarthrosis of the hip*	*age*		*Estimated incidence of new cases of osteoarthrosis of the hip as a rate per million population England and Wales 1978*		*Operations (Codes 810 and 811) carried out in NHS hospitals in England and Wales for osteoarthrosis of the hip as a rate per million population England and Wales 1978*	
Wilcock – Oxfordshire 1970s	Symptoms in excess of minimum threshold for hip replacement (see text) and fit for surgery	65+	M	—		M	1,200
			F	—		F	1,324
			P	450 ± 140		P	1,242
	Symptoms in excess of minimum threshold for hip replacement (see text) whether judged otherwise fit for surgery or not	65+	M	960 ± 360		M	1,200
			F	1,000 ± 240		F	1,324
			P	1,080 ± 210		P	1,242
	Symptoms suggestive of osteoarthrosis of the hip whether above or below the minimum threshold for surgery	65+	M	1,640 ± 470		M	1,200
			F	1,930 ± 330		F	1,324
			P	2,060 ± 300		P	1,242
Danielsson – Sweden early 1960s	Structural and/or joint-space changes evident from roentgenography. Presence of osteophytes alone insufficient. Rheumatoid arthritis excluded. No measurement of pain or disability.	65+	M	3,040 ± 470		M	1,200
			F	1,200 ± 210		F	1,324
			P	1,960 ± 230		P	1,242
		45–64	M	570 ± 230		M	416
			F	1,000 ± 350		F	440
			P	710 ± 180		P	429

Note Error limits are derived from square roots of the numbers of events upon which prevalence rates were calculated.

Source Based on survey data reproduced in Figure 4. For details of method see Appendix 2.

over 65 year olds is less than half the number of operations performed in 1978. Even allowing for the inclusion of bilateral and revision replacements there still appears to be a substantial excess of operations over calculated new cases. When the prevalence rate is extended to include people over the given symptom threshold, whether considered fit for surgery or not, then the calculated flow of new cases reaches about the same order of magnitude as the number of operations. Only when the prevalence rate is extended to include all persons with symptoms suggestive of osteoarthritis of the hip, whether considered fit for surgery or not, does the calculated flow of new cases substantially exceed the number of operations performed among over 65 years olds. Comparable results are obtained from Danielsson's (unrestrictive) radiologically measured prevalence rates among 45–64 year olds and 65+ year olds in Sweden.

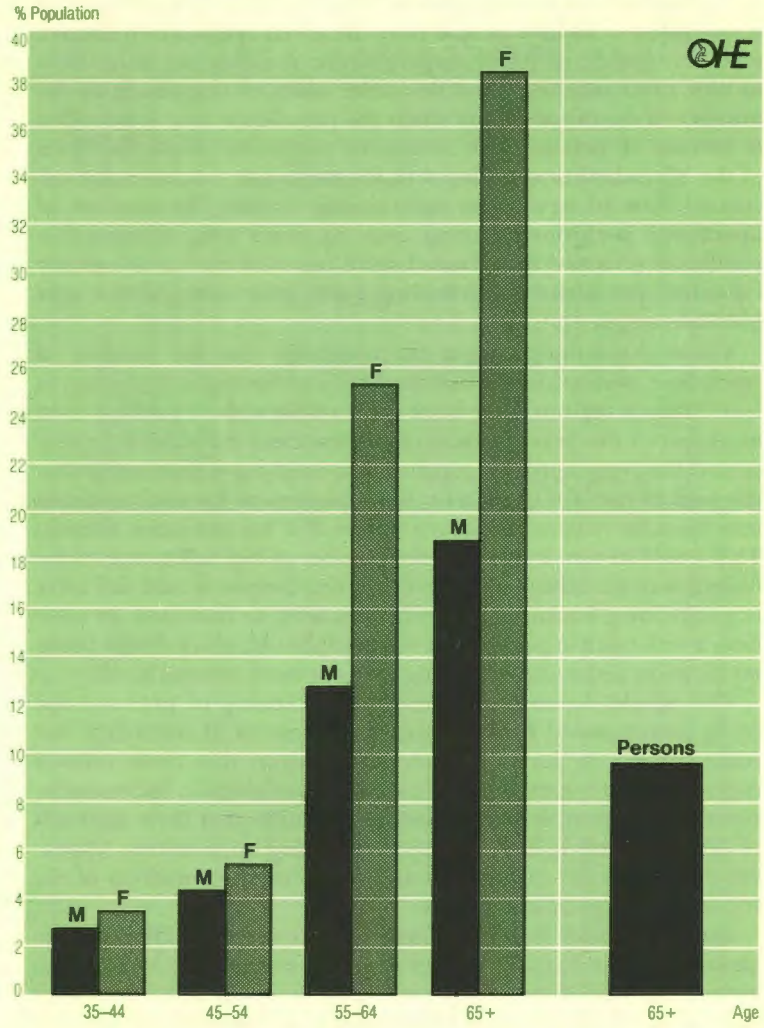
These calculations suggest the possibility that the number of operations performed for osteoarthrosis of the hip in 1978 may, at least in some regions, have been comparable with or perhaps even in excess of the yearly incidence of new cases suitable for operation. If this, very tentative conclusion is valid this would imply that the peak of the 'S' (Figure 1) for hip replacement for osteoarthrosis may soon be reached in some regions, if it has not been already. This would in turn imply that the number of hip replacements for osteoarthrosis, though not for other indications, would fall after the remaining backlog had been dealt with or had died. In addition, a reduction in pressure of demand should, other things being equal, allow reduction of waiting times to more normal levels.

This would depend, of course, on slackening of pressure not being accompanied by an extension of criteria of suitability. But some reports, in particular Wilcock's, suggest that those criteria may, in some regions, be close to their limits already. Such conclusions, which must be treated with the caution that their methods of derivation merit, have important planning implications. Appendix 2 describes the calculations and examines the sensitivity of the results to changed assumptions.

An earlier study by Morris (1975) came to a rather different conclusion. On the basis of figures available at the time Morris suggested that resources for hip replacement would be saturated by the mid 1970s. To an extent his analysis was vitiated by the lateness of HIPE data and the anomalies in operation codes referred to above. More fundamentally, however, he did not have any data on potential demand, such as that provided more recently by Wilcock. In its absence he appeared to assume that it was substantially in excess of any foreseeable level of services. Thus any slowdown in growth of operating rates would be interpretable as a consequence of saturation. Assuming this would soon occur he then extrapolated available data to make a projection, which has since entered the mythology of the subject, of a requirement of one new

Figure 5
Prevalence of osteoarthrosis of the knee

a) Lawrence, Bremner and Bier 1966 **b) Wilcock 1979**



a)

Population: Sample of 1,545 persons from Leigh and Wensleydale, late 1950s.

Diagnostic Criteria: Radiological grade 2–4 osteoarthrosis of the knee together with present or past pain. Including those with rheumatoid arthritis.

b)

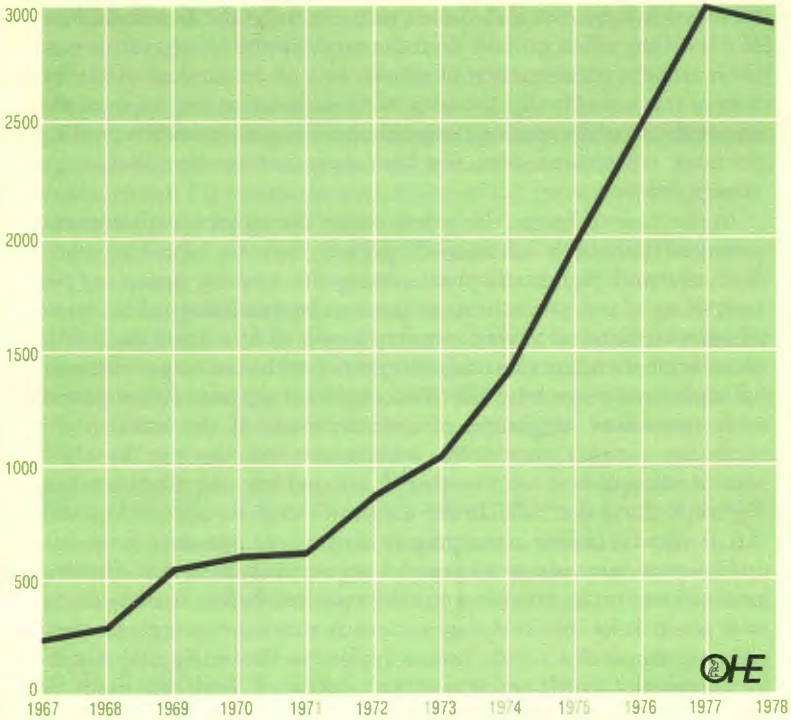
Population: Sample of 828 persons from Oxfordshire in mid 1970s. Aged 65+.

Diagnostic Criteria: All persons with symptoms suggestive of osteoarthrosis of the knee.

Sources Lawrence, Bremner and Bier (1966), Wilcock (1979)

Figure 6 *Estimated numbers and rates of arthroplasties of the knee (OPCS Code 812) performed in NHS hospitals in England and Wales*

a) Numbers 1967–78



b) Rates per million population by diagnosis, age and sex 1978

		15–44	*45–64*	*65+*	*All Ages*
Osteoarthritis ICD 713	M	2	27	59	17
	F	—	38	167	48
	P	1	31	125	33
Rheumatoid arthritis ICD 712	M	—	26	22	11
	F	9	88	80	48
	P	5	58	57	30
Other diagnoses	M	7	17	7	10
	F	1	20	37	14
	P	4	19	26	12

Source HIPE. (b) from Table D additional, unpublished.

300 bed specialist hospital each year to keep pace with increasing demand.

In the event, after a dip in 1973, operating rates continued to increase throughout the middle 1970s (Figure 2). A slight drop occurred in 1978. But if this does turn out to be the first indication of a levelling off in growth then the analysis above suggests it is as likely to be a consequence of satisfaction of demand as of saturation of services. Finally, the idea of 'saturation' in the sense of the impossibility of increasing national operating rates within existing resource constraints does not bear examination (see *Waiting for surgery*, below).

In the case of knees, the other major site of joint replacement, potential demand is substantially greater than for hips. Lawrence, Bremner and Bier found that, among the over 65 group, 19 per cent of men and 38 per cent of women had radiological evidence of intermediate to severe osteoarthrosis of the knee (including those with rheumatoid arthritis) together with past or present pain (of undefined severity) while Wilcock found 9.7 per cent of people with symptoms suggestive of osteoarthrosis of the knee in the same age group (Figure 5). But comparison with the level at which NHS 'Arthroplasties of the Knee' are performed, illustrated in Figure 6, show that, whichever diagnostic criteria are used, potential demand is orders of magnitude in excess of present provision.

However, in practice substantial improvements in the effectiveness of knee replacements would be required before the operation rate could 'take off' in the same way as that for hip replacements did (see Appendix 1). The same applies to the other major joint replacements which are at present performed, experimentally, at only a few centres. Thus the vision of a burgeoning skeletal repair service, imposing new strains on the health services, is unlikely to become a reality in the short or even medium term. And in the longer term, of course, it is to be hoped that some new means of prevention or a cheaper medical treatment of arthritis will obviate the need for surgical intervention.

There are, unfortunately, no reliable comparative data on the level of operations that other counties have achieved. Yet it is interesting to note that in the USA, which has one of the highest levels of surgical activity in the world, it has been estimated (Hori *et al* 1978) that 80,000 total hip replacements were carried out in 1976, about the same order per unit population as Britain. On the other hand, proportionately many more of the difficult and less successful knee replacements were performed, an estimated 40,000 in 1976. Despite the fact that FDA restrictions on the use of bone cements may have caused a development lag in replacement surgery in the US, the American figures on hips are reassuring from a UK viewpoint

Benefits and costs

Should health authorities promote more joint replacements? Should orthopaedic surgeons use more of the resources they control on these operations rather than others? And if so, to what extent should additional operations be used to lower the threshold of acceptance for surgery as against increasing the pace of throughput at present threshold levels? These questions, aimed at different levels of decision making, arise naturally from the widespread consensus that replacement, and in particular total hip replacement for osteoarthrosis, is one of the most rewarding interventions in the surgeon's repertoire.

Surprisingly, however, very little empirical work has been done on evaluating such an important activity. Large gaps exist in those areas where most important benefits are believed to be generated. The conclusions that can be drawn, therefore, are inevitably limited. In particular, only informed guesses can be made as to the relationship between average and marginal costs and benefits. The distinction between these is particularly important since although average benefits of hip replacement appear greatly to exceed the costs, the balance between costs and benefits among 'marginal' patients is not so self evident. There is no comprehensive information on treatment patterns, which would enable present 'marginal' cases to be characterised, although they do not seem to be drawn from any one age group, since operation rates vary by region in much the same proportions at all ages. The merits of policies designed to extend provision at the margin depend on their financial consequences, the effectiveness of replacements in enhancing health status and the frequency and severity of side effects or prosthesis failure. The three subsections below deal with each of these in turn.

Financial costs and benefits

The cost of an NHS joint replacement can be estimated at a minimum of £1,200 in 1981 prices. This gives a total cost of £18 million (£1981) for the 15,330 NHS hip replacements (codes 810 and 811 combined) carried out for osteoarthrosis and rheumatoid arthritis in England and Wales in 1978. The estimated 2,900 knee replacements cost about £3.5 million.

These are crude average estimates derived by multiplying national mean duration of stay for 'arthroplasty' (in the absence of figures specific for hip replacement) by costs per bed-day (including 'hotel' items) in orthopaedic hospitals (as the best estimator of an orthopaedic procedure). An allowance has been made for the cost of the prosthesis but none has been made for the major nature of the operation or for the extra costs of pathology, which may be very high when infection and response to antibiotics are being monitored. Nor has any allowance been made for post-discharge GP and community services.

In return for this expenditure, it has been maintained that society reaps a substantially greater economic return through avoidance of disability and savings in other health and welfare spending. Taylor (1976) estimated that, for a maximum NHS expenditure of £15 million hip replacements probably generated a total return (excluding intangible factors like relief of suffering) in economic resources of £60 million (1974 prices). He calculated a benefit/cost ratio of at least 10:1 for the under 60 age group and of at least 2:1 for 60–70 year olds.

These remain the best available figures on the resouce implications of hip replacement. They are based on estimates of earnings of younger people rehabilitated by hip replacement (the major item) and savings of public and private expenditure on care and support for disabled persons. A more recent investigation of the community benefits of hip replacement (Wilcock 1978) suggests that average benefits in terms of savings of public health and welfare resources may have been overstated by Taylor. On the other hand it focused attention on significant benefits for family or other persons freed from tasks previously performed for the patient.

Those persons for whom, according to Taylor's analysis, the highest benefit/cost ratios would apply are under 60 years old with arthritis sufficiently severe to cause long-term absence from work. It is probable, though there are no empirical data to confirm it, that all or nearly all of these will receive a hip replacement with relatively little delay. But, as is noted above, it is the benefit/cost profile of the 'marginal' patient that is more germane to decisions on resource use.

Wilcock's data (1979) suggest that some patients are borderline because of age and frailty while others are on the margin of suitability because of non-severe symptoms. To the extent that they are old and frail, employment is irrelevant and, as Taylor points out, a successful operation may, by alerting the relevant agencies, even lead to a post-operative increase in use of health and welfare resources. Thus few if any resource benefits may be expected to accrue from surgery among the oldest recipients. And similarly in the case of those with non-severe symptoms, few resources may be foregone by refusing or delaying intervention. The implication is that incremental changes in the provision of hip replacements may not be justifiable by reference to resource gains.

It is also possible, though there are no supporting data, that in some regions further lowering of the threshold of suitability for surgery would not be justified in health status terms either. Some operations may in reality confer little advantage on recipients. For example, for some very old patients, with a high risk of post-operative mortality, well managed, intensive analgesic therapy may be a better alternative.

Marginal patients can, however, be viewed from a different perspective, and one which is particularly relevant to hip replace-

Table 5 *Average costs of medication and social security payments attributable to recipients of unilateral hip prostheses.*

Years before operation	*Average cost in year (£s)*
2	220
1	445
0	1,052

Source Mapes R E A and Austin R (1980). Economic aspects of hip replacement surgery. Medical Sociology Research Centre. University College of Swansea.

ments, by investigating the anticipated net benefits from reducing waiting time among those people already above a given threshold of suitability. This approach was adopted by Mapes and Austin (1980) who measured the progression of costs, in the period immediately prior to operation, among a sample of 45 people in Wales, operated on between 1977 and early 1979. In the course of interviews a picture emerged of pain and stoicism before and after being placed on the waiting list for surgery. Data obtained on the (implicitly avoidable) costs of medication and social security payments are set out in Table 5. The authors measured social security transfer payments rather than attempting to measure the resource costs of employment, but, given that they move in the same direction, these data provide support for the view that, among some groups of patients, there are substantial returns, in both resource and health status terms, from incremental changes designed to speed throughput and reduce waiting times.

Health status

Many clinical studies have shown excellent results in terms of relief of pain and improvement in hip mobility following total hip replacement[11] (Charnley and Cupid 1973, Bentley and Duthie 1973). Directly ascertained patient satisfaction has also been shown to be strikingly high apart from a small, but important, minority of cases. In a study covering one thousand hip replacements carried out in 32 centres in 1975, recipients were asked to complete a questionnaire 9 to 15 months after surgery. Ninety per cent responded affirmatively to the question 'Are you pleased with the result?' The major benefits perceived were relief of pain and increased walking ability (Kay and Harrison 1978).[12]

11 Total hip replacements for osteoarthrosis and rheumatoid arthritis alone are considered in this section. Results for knee replacement are both poorer and less certain.

12 Patient satisfaction, however, does not imply fulfilment of expectations. Thus Haworth *et al* (1981) found 97 per cent of their sample of recipients were satisfied with relief of pain but nevertheless 10 per cent were disappointed because expectations were not fulfilled. Corresponding percentages for mobility were 92 per cent and 15 per cent. There is a hint in Haworth's paper that doctors' optimism may in part be reponsible for disappointment. Doctors were found to be significantly more optimistic than occupational therapists as both predictors and assessors of outcome.

Seeking a more comprehensive view, the literature on evaluation has been increasingly concerned with the whole range of medical and social burdens of disease. There are now a number of structured schedules of questions designed to elicit concise, valid and reproducible indices of health status before and after operation. They share much common ground in measuring pain, mobility, ability to undertake personal care and to engage in domestic and social activities. In general they confirm that the main benefits of total hip replacements are relief of pain and improvement of mobility (Haworth *et al* 1981, McDowell *et al* 1978, Wilcock 1978, Viscuri and Honkanen 1978).

Such techniques are probably in use in only a small number of research orientated centres. There are at least two strong reasons for extending their use, in a standardised and easily applied form, to routine practice throughout the country. First, they could form the basis of outcome measurement in different sub-groups of recipients. Although it is known that people with rheumatoid arthritis gain in clinical terms less from replacement than those with osteoarthrosis, no data exist on the variation in benefit derived amongst the latter. A profile of expected benefits, for example by age and by pre-operative symptom level, could go a long way towards identifying the sort of cases where benefits are large and where they are relatively small. This may in turn go some way towards informing the marginal decisions that both clinicians and health authorities take.

Second, the routine use of these measurement techniques could clarify the extent to which clinical criteria of suitability for surgery vary throughout the country. It is known that regional variations in operating rates are considerable but they may partly reflect differences in prevalence at given threshold levels. Thus although it may be suspected that individuals with similar levels of pain and disability do not receive equal treatment in different regions, no empirical data as yet exist to confirm or refute the suspicion. If, as seems likely, it were found that geographical equality of access does not exist, this would presumably be a matter of some concern to the National Health Service, bearing in mind the importance of the operation as an indicator of NHS performance to both its advocates and its critics.

On the broader issue of the comparative value of improvements in health status, it has to be admitted that the units in which hip function and disability indices are measured could rarely allow direct comparison with other ways of spending health service resources. Thus they are not very helpful in informing questions of broad priority in different services. This is in part a consequence of failure of different disciplines and different specialities to co-operate in developing common indices. Although no one should underestimate the difficulties of such a task, sections of the research community can be justifiably criticised for insularity.

Durability and side effects

Given the chequered history of joint replacement (see Appendix 1) it is not surprising that surgeons have been cautious about extrapolating from the short to the long term. Studies with follow up ranging up to 10 years indicate continuing complete or nearly complete relief of pain in 80–95 per cent of hip replacements and significant improvement in function in 80 per cent of implants remaining *in situ*. But a key point that has not yet been fully answered is the expectation of very long term survival of the prosthesis. The most recent and longest follow ups give grounds for optimism that even among younger patients the number of present day implants which fail before death, and so require re-implantation or some other less acceptable form of 'salvage', is likely to prove acceptably low – at least for those patients who, without the operation, would remain in severe pain.

Dobbs (1980) has provided the most relevant data so far, from a series of 248 metal on plastic prosthesis inserted at the Royal National Orthopaedic Hospital between 1969 and 1972. Figure 7 indicates that actuarial survival (defined as the implant remaining *in situ* regardless of any attendant pain or loss of function) was 88 per cent at 8 years, the limit so far of the follow up. Among survivors at least 90 per cent had little or no pain and were sufficiently active to cope with their daily needs.

The extent to which the survival curve will have altered in the intervening ten-year period is, of course, unknown. Some improvement might perhaps be anticipated with further refinements of design, materials and operative techniques. In the past the introduction of the former two was controlled only by clinical judgement. The DHSS has now proposed a scheme whereby an approved list of prostheses would be established (Sweetman 1981). It depends on voluntary observance by orthopaedic surgeons, and has been welcomed by their representative body, the British Orthopaedic Association. But it may be rather less useful, now that there is wide consensus over designs and materials, than it would have been in earlier years, when experimentation was more cavalier.

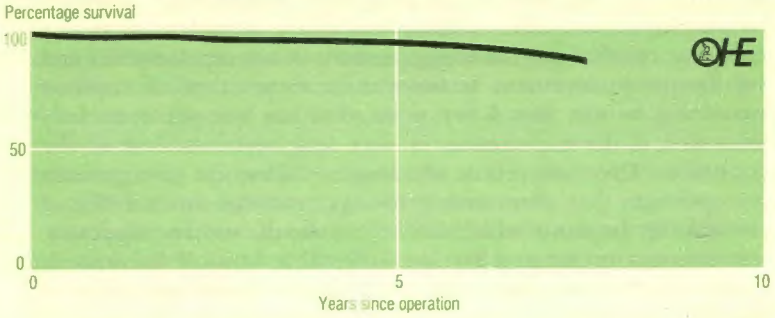
It is apparent from Figure 7 that replacement hips do not have an unlimited lifespan. A proportion of re-operations must, therefore, be anticipated within the lifetime of recipients. Provided the general state of health remains good these can offer an extension of the relief originally obtained.

But apart from any 'wearing out' process, a small but important minority of hip replacements, about 10 per cent, are unsatisfactory from the outset.[13] Where failure can be attributed to a specific,

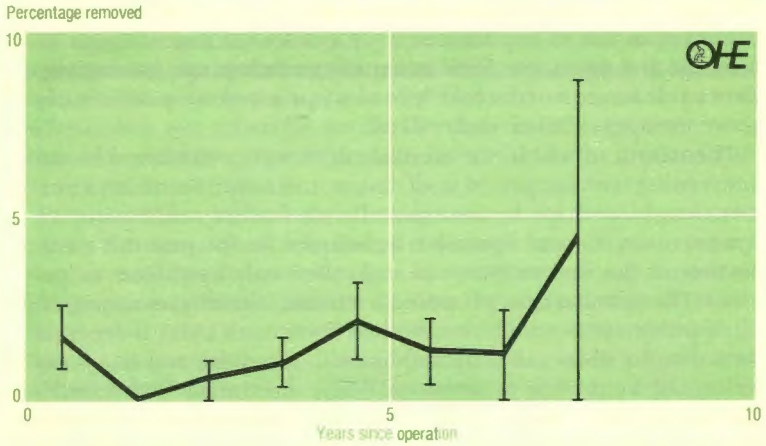
13 Mortality rates prior to discharge have recently been running at 1 per cent for hip replacements carried out for arthritis (HIPE Table D Additional). These reflect the age structure of the operated population. It is interesting to note, in passing, that such a level of mortality would be considered quite unacceptable for a medical treatment.

Figure 7 *Metal in plastic total hip replacements carried out at The Royal National Orthopaedic Hospital 1969–72.*

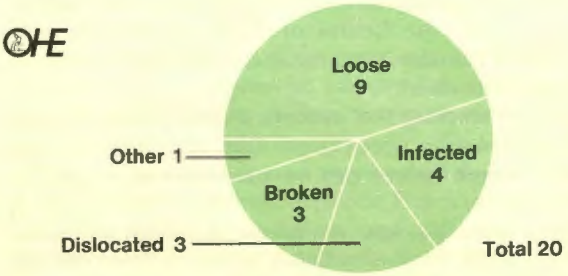
A. Percentage survival after given time period.



B. Annual probability of removal as a percentage of implants at risk in a given year



C. Causes of removal (total numbers)



Source Dobbs H S (1980). Survivorship of total hip replacement. *Journal of Bone and Joint Surgery*, 62B/2.

non-infective cause, re-operation usually offers a satisfactory solution. Where, however, the problem is infection the prognosis is often grave. Published infection rates have varied from the very low (0.5 per cent) to the clearly unacceptable, 15 per cent. The average is about 2 per cent under current practice. In most cases the prosthesis is removed and in about half no replacement is inserted (Charnley 1979). Petty and Goldsmith (1980) have described the poor condition of 21 patients, 1 to 8 years after removal of total hip arthroplasty components because of infection. All of them had moderate to severe pain and only 3 were satisfied with 'salvage' resection arthroplasty.

Results of recent trials, however, offer the prospect of substantial reductions in infection rates from both prophylactic antibiotic cover during operation (Hill *et al* 1981), and the use of ultra-clean air systems and body exhaust suits in operating theatres (MRC multi-centre trial results – unpublished). In addition there are as yet unpublished reports that antibiotic loaded cement may on its own be even more effective in reducing infection rates. Society places a very high value on the minimisation of the unwanted effects of intervention. It therefore seems likely that the required extra resources will be available to prevent the severe consequences of infection during operation. A rapid but careful evaluation of costs and benefits of alternative strategies is clearly desirable.

Waiting for surgery

Queuing occurs at two principal points in the NHS system; for out-patient consultation and for admission to hospital for elective surgery. Regrettably little is known, above the anecdotal level, about queuing for out-patient departments, though data collected by the DHSS working party on orthopaedic waiting times (HMSO 1981) suggest that they may be measurable in months rather than weeks. Out-patient consultation may be followed by a period of conservative treatment. Thereafter, patients considered suitable for surgery enter hospital by different routes. Eighty-two per cent of hip replacements for osteoarthrosis were in 1978 admitted through the waiting list.[14] It is among these recipients that waiting time may run into years.

Waiting list management is in the hands of clinicians, except in so far as it is delegated to others such as theatre or ward nurses, secretaries or, occasionally, specifically designated non-medical clinical managers. Systems vary widely though they tend to have some features in common. First, they are usually open, that is a suitable person will be accepted on to the list even if there is little

14 A further 13 per cent were 'booked' cases, which normally enter hospital within a few months. Four per cent were 'immediate'.

prospect of early surgery. Second, they are generally not first come first served. Most, if not all, are banded such that the most severe cases move into hospital quite rapidly while those seen as the 'least urgent' cases may move very slowly to the head of the queue, unless a change in symptoms allows reclassification to a more urgent band. It appears to be a characteristic of such systems that they give little weight to length of time spent on the list *per se*, but give something akin to absolute priority to clinically more severely affected people, just as prior absolute priority is given to emergency admissions for fractured femurs. The parallel with local authority housing lists, with their active and non-active sections, is clear.

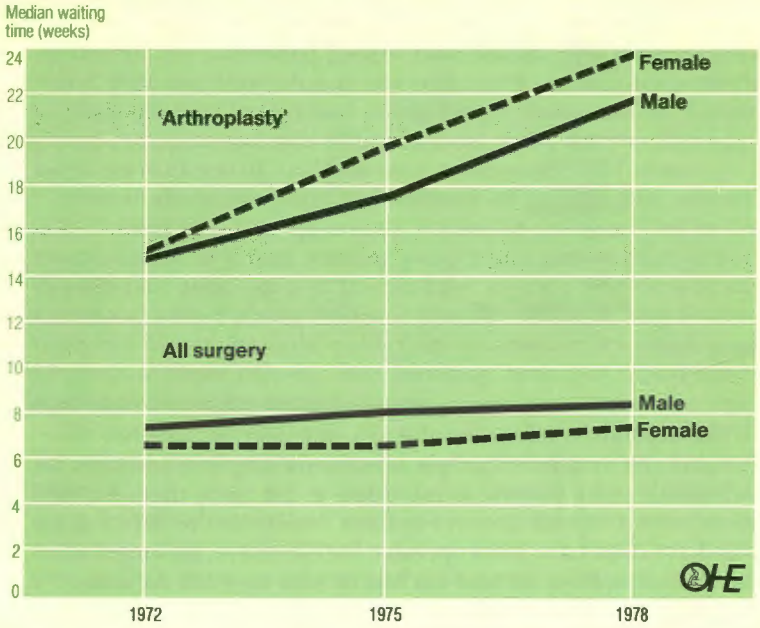
Recorded dates of entry on to waiting lists generate national data in two ways. First, they are used to calculate the distribution of waiting times amongst the people actually admitted to hospital in the year in question. Figure 8 shows that median waiting time for 'arthroplasties', the bulk of which are hip replacements for osteoarthritis, was, at 23 weeks in 1978, about three times higher than that for all surgical cases in all departments admitted from waiting lists. And, while median waiting time increased only marginally for all surgery between 1972 and 1978, for arthroplasty it increased by 50 per cent. Furthermore, despite a DHSS circular in 1975 recommending that no non-urgent case should wait more than a year, 19 per cent of arthroplasties from the waiting list had done so in 1978 (6 per cent for all surgery). The regional distribution for median waiting time is shown in Table 6.

These data represent the only useful information generated by the NHS on waiting time and waiting lists. On publication, in HIPE, however, they are 3 years out of date. Besides this, they are in themselves records of past waiting experience and, for the very long-term waiters, bear no necessary relation to the chances of admission for people starting their wait in the year in question.

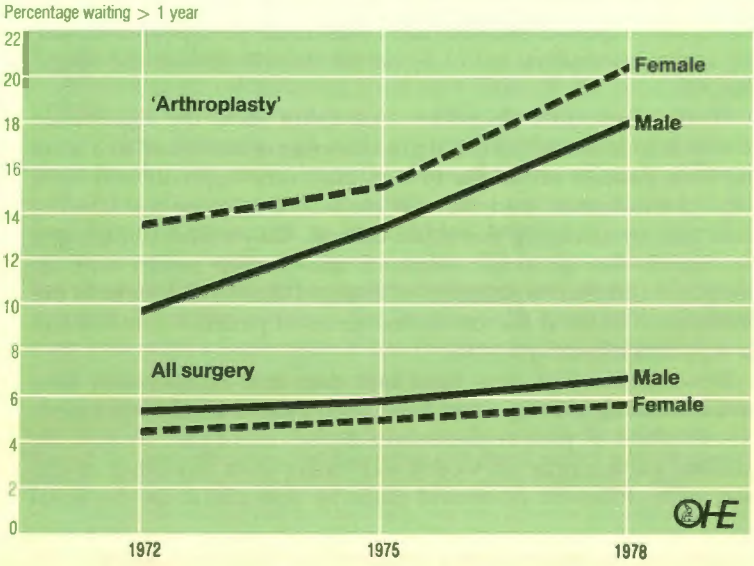
The second set of data produced by the NHS is the twice yearly 'snapshot' view, derived from form SBH 203, of the number of people on waiting lists and the lengths of time they have been waiting. These are more up to date but they are grossly misleading for two reasons. First, they give an exaggerated impression of the proportion of people waiting for long periods. The probability of a case being on the waiting list on a given day, and thus being sampled by SBH 203, is proportional to the length of time it remains on the list. Thus, if most cases are entering and exiting from the list fairly rapidly, and a minority are relatively immobile, the immobile minority would account for a major proportion of the list on a particular day. The snapshot view gives rise to the statistic that 38 per cent of non-urgent cases on orthopaedic lists at 30 September 1979 had waited more than a year. The danger is that this might be interpreted as saying that 38 per cent of all recipients wait for more than a year.

Figure 8 *Waiting times for 'Arthroplasty' (OPCS Code 100). All persons admitted to hospital from waiting lists*

a) Median waiting times 1972–78



b) Percentage who had waited for more than one year



Source HIPE various years

Table 6 *Median waiting time for 'arthroplasty' among persons admitted from waiting lists, by region or residence, 1978.*

Region	*Median waiting time (weeks)*
Oxford	18.8
Combined Thames	19.6
Yorkshire	19.9
Northern	21.8
Mersey	21.8
Wessex	23.1
N Western	28.1
E Anglia	28.1
W Midlands	29.2
Trent	31.3
S Western	33.7
Wales	—
England and Wales	23.2

Source HIPE.

The second limitation of the SBH 203 data is that they overestimate the number of people actually waiting. It is common for individuals to be on two or more lists at the same time. Furthermore, most hospitals do not regularly review lists to delete those who have died, have been operated on elsewhere, no longer want the operation, have become too frail or who have left the area.

Laurie (1978) has illustrated the magnitude of the discrepancy that might arise among people on the list for long periods. He circularised 213 patients placed on an orthopaedic list between 16 and 40 months previously (mean 25 months). For total hip replacements the responses showed that a maximum of 12 people (including 4 non-responders) out of 27 on the list still wanted the operation.[15]

Finally, there must always be some doubt about the significance to attach to levels of, and changes in, even regularly updated waiting lists. Policies on access to lists may vary unpredictably with local circumstances and there is considerable scope for altering their size by changing threshold criteria. Culyer and Cullis (1975) concluded that a simple demand and supply model was inadequate and that explanation of changes should be sought in the dual role of hospital doctors as the agents of patients' demand and as suppliers of services.

Nevertheless, it is clear from HIPE data that exceptionally long and increasing waiting times have been experienced by prospective recipients of joint replacements in the recent past. In 1978 the median waiting time (23 weeks) was longer than any other operation code, followed in second place by operations on the nasal

15 For all orthopaedic operations comparative figures were 153 (including 89 non-responsers) out of a total of 213.

septum (18 weeks). This is in part attributable to a rapid manifestation of potential demand induced by the popularity of the operation and the inevitable lag while expertise diffused among orthopaedic surgeons. But it is also related to more general problems of the speciality of orthopaedic surgery. Waiting times in the speciality overall are somewhat longer than for all departments combined. Figure 9 shows that 10 per cent and 8 per cent respectively of cases admitted in 1978 had waited longer than one year,[16] while 5 out of 10 operation codes (out of a total of 120) with median waiting times in excess of 3 months were orthopaedic operations.

Unease about the poor performance of orthopaedic surgery, and concern about an apparently worsening position,[17] led to the establishment of a DHSS working party which published its report in early 1981 (HMSO 1981). It accepted the strongly held view of surgeons and nurses giving evidence that the origin of long waiting times lies in competing demands from traumatic cases which must be given absolute priority, thus 'blocking' beds that would otherwise be available for elective surgery.

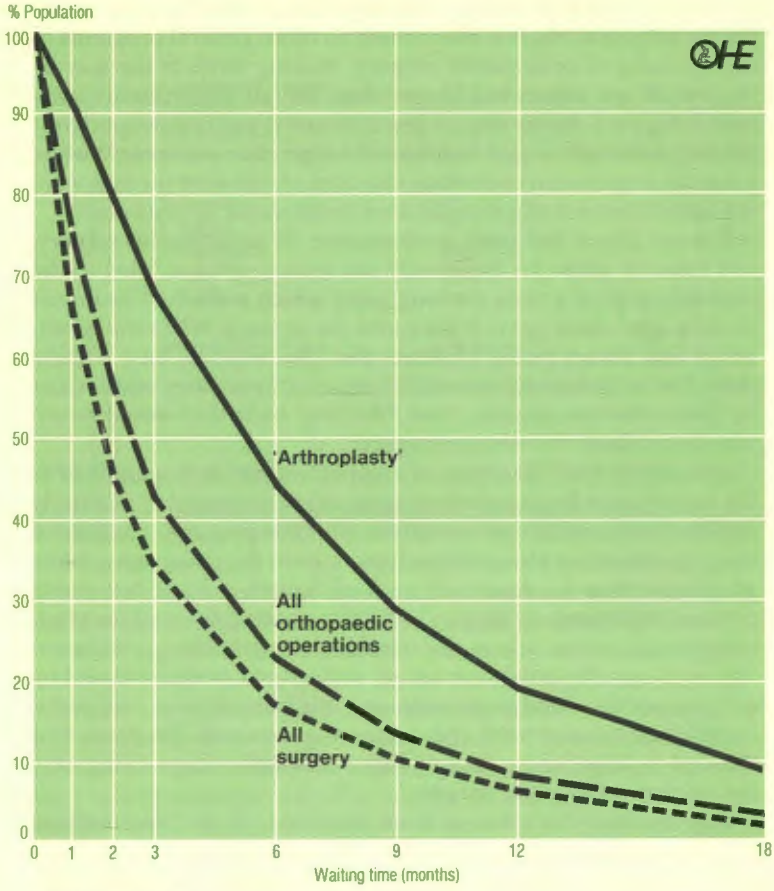
The report read: 'In terms of competition for orthopaedic beds the pattern may be summarised as an increasing number of elderly patients (an increase due not only to the changing age structure of the population but also and much more so to the rising age specific admission rates for fractured neck of femur), a large but stable demand for traumatic surgery and an increasing demand for elective surgery, particularly in the treatment of arthritis' . . . 'Between 1969 and 1978 the total number of orthopaedic beds increased by only 0.5 per thousand population and this increase was, it appears, insufficient to cope with the competing demands on them and thus led to lengthening waiting lists and lengthening waiting time for elective orthopaedic surgery.'

Approximate calculations, from HIPE data, of the contributions of different factors to orthopaedic workloads, support the working party's view. Between 1968 and 1978 combined age adjusted admissions for the two major 'growth' areas of fractured neck of femur and arthroplasty increased by about 40,000 per year. Ageing of the population is estimated to have added another 60,000 cases (all causes of orthopaedic admission) a year. The total accounts for all the observed rise in orthopaedic discharges and deaths (Table 7), apparently leaving no room for lowering the threshold of admission generally, a factor which has frequently been suggested as a

16 The figures for all surgery are dominated by the speciality of general surgery, with a median waiting time of about half of that for orthopaedic surgery in 1978. Among the other specialities, ophthalmology and dental surgery had comparable waiting times while ear, nose and throat and plastic surgery had higher ones.

17 Orthopaedic waiting lists increased by 31 per cent between 1977 and 1979, compared with 16 per cent for all surgical specialities. Even bearing in mind the limitations of the data source, this probably signifies a real deterioration, and a relatively rapid one in orthopaedic surgery.

Figure 9 *Distribution of waiting times among persons admitted to hospital from waiting lists. England and Wales 1978*



Source HIPE 1978

cause of increased workload in the hospital sector. It seems likely, therefore, that at whatever level of efficiency orthopaedic departments have been operating (and the variation is certainly considerable) pressure to obtain more from existing resources, unbuffered by slack in threshold levels, has been a continuing feature of clinical practice. In these circumstances it is not surprising that waiting times for elective surgery have increased.

There are, broadly, four ways in which waiting times may be reduced; by changes in expressed demand, by more intensive use of NHS resources, by provision of extra NHS resources and by extension of private sector activity. These are considered, in turn, below. It is the second approach, increasing the productivity of existing

beds, operating theatres and surgeons, that seems to offer the best prospects for improvement. The section ends by looking at improvements in data recording which would greatly facilitate realisation of the full potential of existing NHS resources.

Changes in demand

The possibility has been noted of a stabilisation and perhaps even a reduction in the medium-term future in expressed demand for hip replacements for osteoarthrosis. Prevention of arthritis is a much longer-term possibility. It is largely dependent on continuing research into its causes and development. Elucidation of the mechanisms of rheumatoid arthritis could lead to medicines capable of arresting the process of inflammation and damage to the joint. For osteoarthrosis, however, there seems to be no imminent prospect of better understanding.

Kelsey (1977) makes the point that, although stress in the hip joint undoubtedly plays a role in pathogenesis, there is controversy over the nature of the stress which leads to osteoarthritic changes. Farmers and gardeners are at high risk but the areas of the joint where changes are first seen are not those subject to the most stress. The low prevalence of osteoarthrosis of the hip among Asians may be attributable to frequent squatting allowing all areas of articular cartilage to be subject to pressure each day. Thus the nature and area of stress may be important and no simple rules of

Table 7 *Trends in orthopaedic surgery in-patient statistics 1967–1978.*

1) Average beds used daily. England and Wales (1,000s).

	1968	*1978*
Arthroplasty	1.2	2.7
Treatment of fractures by operations	3.8	4.7
Other operations	5.8	4.0
Other admissions	5.8	6.5
Unoccupied	2.5	4.5
Total available beds	19.2	22.3

2) Cases. England and Wales (1,000s).

	1968	*1978*
Arthroplasty	11.4	38.0
Treatment of fractures by operation	80.8	119.5
Other operations	123.8	119.0
Other cases	154.0	196.0
Total discharges and deaths	370.0	472.5

Source HIPE, Health and Social Services Statistics.

behaviour can be suggested for individuals to guard against the disease in middle or old age.

Obesity has (though not consistently) been reported as related to osteoarthrosis of the hip and (consistently) with osteoarthrosis of the knee, but which is cause and which is effect is not clear from the data. After the appearance of symptoms, conservative medical treatment may perhaps delay the progress of arthritis to the point where surgical intervention is necessary and it has been hinted that some drugs may also have a protective effect. But in summary there is little immediate potential for a major reduction in workload from prevention of osteoarthrosis.

Apart from joint replacement, the other major cause of increased, and competing, in-patient workload has been admissions for fractured neck of femur. Fenton Lewis (1981) has estimated that the age adjusted component of the growth observed between 1968 and 1977, Figure 10, amounted to 70 per cent. The reasons for the rise in age specific admission rates are controversial. It is, therefore, not known whether the trend will continue upwards in the future. Some increased workload may, however, be anticipated from the very oldest female age groups, whose numbers will grow on into the next century.

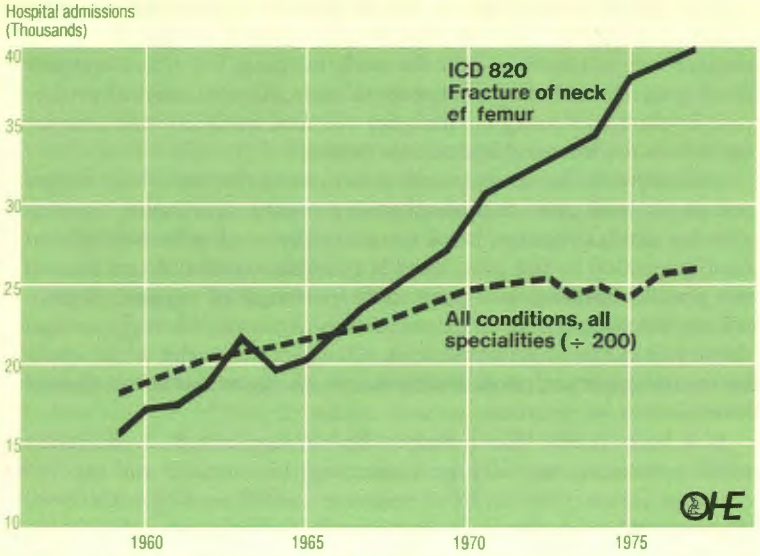
In the medium to long term there is some potential for reduction of traumatic workload by effective preventive measures, especially for accidents in the home, at work and on the roads. Seat belt legislation, if effective in reducing injuries from road accidents, could provide one practical means of relief.

As regards new techniques, it has been noted above that improvements in knee replacements could lead to significant new demands on resources. Spinal surgery could also be a source of technology led demand. Finally, demand mediated through clinicians may be modified by changes in threshold levels for admission. But it seems unlikely that a significant reduction in workload could be obtained (even if desirable) by this means.

More intensive use of existing resources

In 1978 the Oxford region, with a below average number of orthopaedic beds per unit population and even fewer consultant surgeons, managed to achieve one of the highest rates of hip replacement and the lowest median waiting times. In general, there appears to be no relationship between *per capita* levels of major hospital resources on the one hand and operating rates or waiting time on the other. Linear regression analysis using (1) available beds – after subtracting the average number occupied by non-waiting list cases (2) whole time equivalent consultant surgeons and (3) orthopaedic theatre sessions (per unit population) as independent variables failed to explain regional variations in 1978 in either operating rates or median waiting times. This applied equally to all orthopaedic operations and to arthroplasties alone. R squared values were all

Figure 10 *Estimated hospital in-patient admissions (England and Wales) for fracture of neck and femur and all conditions. Admissions for 'all conditions' reduced to comparable scale by dividing by 200.*



Source A Fenton Lewis (*1981*). Fracture of neck of the femur: changing incidence. *BMJ 283, 1217–20.*

low and estimated coefficients of the independent variables were as often negative as positive.[18]

Thus although there may be some orthopaedic departments which are operating at the limit of their physical capacity, the view that this is typical thoughout the country is untenable. Empirical investigation confirms that particular resources are utilised to only part of their capacity. Thus a recent Medical Architecture Research Unit survey (see footnote 18) of operating theatre use found that the average working time per theatre per year was 37 weeks compared with the DHSS norm of 50.

The importance of bank holidays as a cause of lost sessions is illustrated in a 1978 study of a single area. Cliff (1980) found that 'statutory holidays' accounted for 31 per cent of all sessions lost, followed by non-availability of theatre staff such as nurses and technicians (25 per cent of lost sessions) and of medical staff, mainly anaesthetists (a further 11 per cent).

The Working Party on Orthopaedic Services, commenting on

18 Data on operating theatre sessions per unit population were taken from a survey of 377 hospitals in England with two or more operating theatres, carried out by the Medical Architecture Research Unit at the Polytechnic of North London. Included in the information collected was the number of scheduled operating theatre sessions in a sample week in June 1979 by speciality (MARU 1981).

the 'domino effect' of public holidays whereby admissions on days following holidays are curtailed as well, pointed out that 'during the Christmas to New Year period it is not unusual for no elective surgery to be carried out at all'. It further commented on staff availability 'that it was not uncommon in the past for afternoon theatre lists to continue into the early evening, but nowadays it is frequently difficult for a surgeon to start an operation after 4.30 pm. Extra duties and overtime for elective work are not encouraged both for financial and social reasons.'

Undoubtedly there are many instances of the other two major resources, beds and surgeons themselves (OHE 1981) being unavailable for similar reasons, but a return to the work ethic believed to have prevailed in the past, even if possible, could only go part of the way to realising the productive potential of surgical departments. What information exists, most of it anecdotal, suggests that the key to major improvements in efficiency lies in the wider application of simple techniques of resource management at the clinical level.

It is only rarely that orthopaedic (or any other) departments make systematic use of information on the number and type of cases on waiting lists and the resource cost of dealing with them. The DHSS Working Party on Orthopaedic Services strongly emphasised the need for such basic tools of management. It went on to recommend for study systems operating in Southampton, Oxford and Hastings. In Hastings, for example, a lay clinical manager has been appointed to organise waiting list admissions and pre-admission clinics are used to do much of the preliminary work, thus reducing length of in-patient stay. In Southampton, cases are expressed as theatre workload units; −7 = major, −3 = intermediate and −2 = minor. These can be applied to waiting lists and, together with data on duration of stay, an assessment can be made at any time of the work facing the unit and the effect of changes in any of the parameters governing throughput.

Certainly, the wider application of systems like these would help to realise much of the potential implicit in unexplained variations in waiting time and operating rates. What is perhaps surprising is that an official report should find it necessary to spell out the sort of procedure which any large organisation might have been expected to have instituted at the earliest possible opportunity.

More resources?

The Working Party on Orthopaedic Services gave considerable attention to the suggestion, argued strongly by surgeons and by nursing organisations giving evidence, that a strict separation should be made administratively, or enforced in practice, between beds occupied by traumatic and elective cases. Only in this way, it was maintained, could trauma cases be prevented from overflowing and 'blocking' beds which would otherwise be available for

planned admission of elective cases such as joint replacements. But in the final report this option was rejected as unrealistic. Instead, the report suggested a flexible designation of beds, pointing to methods by which normal trauma workload can be calculated, thus giving an indication of remaining beds available for elective surgery.

Only if the remaining number is insufficient, the Working Party argued, should more beds be sought in a given hospital or elsewhere in the district. The report went on 'the search for additional beds must of course not start until the other exercises in predicting demand for elective surgery have indicated how many beds are needed and whether part of that need can be met by using existing beds in a more efficient but equally effective way.'

In the longer term, and at the regional and national level, the report pointed to recent questioning of long-accepted norms for acute beds as a whole (Rudge and Richards 1979). It has been argued that they might be recalculated along with the shares of individual specialities, in which case an increase in orthopaedic beds in both absolute and relative terms would be indicated.

It did not venture to suggest which speciality might lose (in beds, theatre sessions and other resources) in a short or longer-term redistribution, but clearly General Surgery is the most likely candidate. Rather, the report emphasised the need for flexibility in sharing resources within and between specialities and the local application of management methods to improve the availability of joint replacements and other elective surgery within existing resource constraints.

Nevertheless, the issues raised by the Working Party have within them the makings of a major medico-political dispute. Given that present financial stringency is likely to remain for the foreseeable future, with no growth money to facilitate gradual redistribution, many clinicians are likely to see a once and for all switch of resources as the primary requirement for relief of pressure on orthopaedic surgery.

The private sector

To what extent, it may be asked, could the private sector contribute extra resources? The private sector, in this context, usually means private hospitals, separate from the NHS. The proportion of total hip replacements carried out in these is unknown, but the ratio of private hospital surgical beds (all specialities) to NHS beds available for waiting list cases suggests that there are some specialities, probably including orthopaedics, where more than 10 per cent of cold surgery is currently done in the private sector. Private orthopaedic operations carried out in NHS pay beds, in comparison, accounted for 2 per cent of the NHS total in 1978 (HMSO 1981).

The net contribution of the private sector depends very largely on the way in which individual surgeons organise their work and

which of the NHS resource components, staffed beds, theatre sessions and surgeons act as constraints in given local circumstances. If surgeons' time is itself a constraint then, given the impracticability of increasing the number capable of performing hip replacements in the short term, a net increase in operations could only be achieved by surgeons working more intensively. The physical separation of NHS from private hospitals adds a travelling time factor for part-time NHS consultants which may make this difficult. There would be no net advantage if surgeons were simply to clear lists in NHS hospitals in order to make time for a private sector session.

If, on the other hand, theatre sessions were the major constraint, available surgeons' time may not be fully used. To the extent that the supply of theatre staff is elastic, a net increase in operations may in this case more plausibly be achieved by use of private facilities. The same applies if, as the Working Party on Orthopaedic Services suggests, staffed beds represent the commonest constraint. There is also the possibility of operations being performed in one sector and post-operative rehabilitation taking place in another.

The regression analysis referred to above found that available beds, theatre sessions and number of surgeons could not adequately explain variations in operation rates by region, whether for hip replacements alone or for all orthopaedic waiting list operations. It provides therefore, few clues as to where the bottlenecks in throughput are most likely to be met. But at the same time it suggests that an organisational factor may be crucial to throughput achieved, a conclusion supported by the emphasis placed by the DHSS Working Party on Orthopaedic Services on the adoption of simple management techniques.

The organisational factor adds an important dimension to the issue of whether, on balance, the private sector can provide a net addition to resources, to the advantage of the NHS. The answer will then also depend on whether additional private practice acts in some way as a spur to efficiency in the NHS, or whether on the other hand it saps the commitment of part-time surgeons to effective management of the NHS resources at their disposal.

Information needs

Deficiencies in waiting list management are not confined to orthopaedics. Rational systems remain in their infancy throughout all specialities. This may partly be attributed to insistence by consultants on maintaining clinical responsibility for selection from lists and partly to the absence of any focus for pressure to undertake rationalisation. Clinicians themselves rarely have the time, or the expertise. And within the NHS there is no other grade of personnel with specific responsibility for this area of activity, despite the fact

that it is central to the functioning of the hospital service and to the satisfaction of its consumers.

A fundamental problem, yet one that is in principle capable of straightforward resolution, is the poverty of information available to clinicians and administrators for waiting list management. A DHSS Steering Group is at present looking at the information needs of the NHS generally. The Working Party on Orthopaedic Services recommended that 'the review of information on hospital clinical activities being conducted by the Steering Group on Health Service Information should include consideration of the introduction of standard systems for the collection of statistics on waiting times for new out-patient appointments, on the availability and usage of operating theatres and on nurse staffing ratios for both operating theatres and hospital wards allocated to different specialities'.

Any review of waiting statistics, however, should go further than this in two respects. First, in-patient data should be revised alongside (at present non-existent) out-patient waiting statistics. Currently, the only meaningful statistics are 3 years out of date when published by HIPE. The more up-to-date figures published on numbers waiting on a given day are both inaccurate and misleading.

A method which would remedy these drawbacks has been described by Yates (1978). He proposed a cohort system for following-up patients placed on a waiting list in a defined time and recording cumulative admissions, deletions and, by subtraction, those still waiting. Waiting list decay curves thus generated could be summed over any time period or any geographical area to give whatever comparison was required.

The merits of this sort of system, and of integrating out-patient data to give total waiting experience, were noted by the Steering Group (DHSS 1981). But the validity of any resulting intertemporal and interdistrict comparisons could still be questioned on the basis of the comparability of people entering (or not entering) the queue. It is for this reason that health status data is an additional key element of any comprehensive system. As well as facilitating comparison of like with like it would make possible relatively sensitive analysis of benefits and costs of policy options in a way that has hitherto been impossible. Although the Steering Group report rightly pointed out that sophisticated epidemiological techniques are beyond the scope of routine statistics collection there need be no insurmountable problem in recording health status once a relatively simple technique has been validated.

Nor, with present computer technology, need cost represent a significant barrier. In the case of potentially operable osteoarthrosis of the hip, self assessment by patients with a standard questionnaire has been found to be both practicable and reproducible (McDowell *et al* 1978). In the context of the present review

of clinical information it would be unfortunate if the opportunity were not taken to develop a framework which was at least flexible enough to cope with the dimension of health status for those conditions and procedures where such information could make an important contribution to the quality of services available to patients.

Conclusions– towards better services

Since the late sixties, when hip replacement started to 'take off', a number of suggestions have been made as to how to increase provision and reduce waiting times. Most have rested on the assumption that services would be saturated long before maximum potential demand had been manifested. The analysis above calls this assumption into question, suggesting instead that, in some regions at least, operating rates may already be at or even above the level required to satisfy the flow of new cases at relatively unrestrictive criteria of suitability. If this tentative conclusion is valid then, when the backlog of old cases is cleared or dies, existing operating rates may even be more than adequate to cope. Some of the suggested initiatives may be re-examined in this light.

One idea floated has been the development of centres specialising in joint replacements alone. The DHSS Working Party on Orthopaedic Services argued against this, maintaining that the more common the procedure the greater the reason for it being provided by every district general hospital. In addition, if hip replacements are near the peak of their diffusion curve, such centres would run the risk of rapid obsolescence.[19]

Another suggestion which has been widely canvassed since the publication of the DHSS Working Party Report is that a once and for all transfer of resources should be made from other specialities (for example general surgery) to orthopaedic surgery. But the prospect of a possible stabilisation in demand for joint replacements, together with the potential for increases in productivity from existing resources, indicates the necessity of very careful research into future patterns of demand to justify any transfer.

19 Besides their supposed role in alleviating strain on resources, it has been suggested that larger specialised centres may show better clinical results. Support has been drawn from an American study (Luft *et al* 1979) which found that mortality rates for certain operations in the USA rose significantly below a certain threshold level of frequency of performance. For hip replacements the threshold appeared to be 50–100 operations per year in a given hospital. Comparisons are vitiated by case-mix differences but such data as exist in Britain provide no support. Thus the Arthritis and Rheumatism Council sponsored study of one thousand hip replacements in 1975 found no evident size dependence of results in terms of patient satisfaction (Kay 1981).

The private sector has been seen by some as the most promising source of extra resources in the acute health services generally. Given that, in some regions at least, long waiting times for joint replacement represent a backlog problem, contracting out operations or post-operative care to the private sector may be seen as an attractive option, as it involves no long-term capital commitment on the part of the NHS. In those localities where a practical advantage to the NHS might be demonstrable in terms of increased throughput, there may be a role for the DHSS in financing itself such arrangements. Though centralist policies are at present unfashionable, there is a case for more direct intervention by the DHSS to ensure equality of access throughout the country for perhaps a handful of highly effective services, including hip replacement.

But in this context it should be also noted that in some instances an extension of private sector activity can only take place at the expense of NHS activity. This is so, for example, where the binding constraint is the availability of experienced surgeons. Then there is no advantage to be gained from contractual arrangements with private agencies. And in either circumstance it is important that authorities be aware that extension of private sector activities brings with it the danger of sapping the vigour with which part-time surgeons pursue effective management of NHS resources.

Finally, it has been suggested that the establishment of a national waiting list could reduce waiting times. In certain regional specialities, such as cardiac surgery, where some localities are substantially better provided for than others, mobility of patients can make for better use of scarce resources. For knee replacements, which are usually carried out in specialist units, there may be similar advantages. But in the case of hip replacements close examination suggests that benefits are likely to be much less than is commonly supposed. In the first place, it is wholly unrealistic to speak in terms of national list as such for a common procedure with ill-defined criteria of suitability. There are many thousands of prospective recipients of artificial hips throughout the country. Information on them is available either by personal contact between surgeons or through case notes. Without standardised and accessible health status data it is inconceivable that importing surgeons could sift through more than a handful of patient records. This raises serious doubts about the extent to which one of the major supposed attractions of a 'national waiting list', the rapid throughput of individuals indentified as priority cases, could be achieved.

In practice, stimulation of patient mobility would depend on local unification of surgeons' lists, abolition of any residence requirement and widespread dissemination of information on expected waiting times for out-patient consultation and surgery. In this way patients could be given a wider range of choice. Any

advantage, however, would depend on the willing co-operation of those surgeons with significant spare capacity, or who may require more suitable patients than they can find locally. These are probably few in number. Any attempt to impose accessibility to all-comers regardless of the views of surgical teams could have a devastating effect on morale. Well motivated units, having made great efforts to cope with local demand might then find themselves asked to cope with a further unlimited source of workload. At the same time, less well motivated units may be encouraged to perform even fewer operations in the knowledge that patients could go elsewhere. In summary, though some patients, especially from severly underprovided areas, would gain from measures to increase mobility, it is unlikely to make a substantial contribution to the availability of hip replacements generally, or to the reduction of waiting times.

A much more important objective is the development of an adequate minimum of services in all localities. Despite some deficiencies the NHS has gone some considerable way to achieving this. It has not, as is sometimes alleged, 'failed' as a system. Most patients are not subjected to an unacceptable wait for surgery; and there is little evidence that Britain's supply of hip replacement surgery falls significantly below that of other Western developed countries. Furthermore, management techniques already introduced in many NHS hospitals offer a real possibility of substantial service improvements within the framework of existing provisions.

Appendix 1 – History and prospects

There are various conditions, including arthritis, trauma and congenital defects, which cause pain and loss of movement in joints. Arthroplasty is the generic term for surgical procedures which attempt to alleviate these problems, whether with use of artificial implants or not. The hip is not the joint most frequently affected by disease. But it has received the greatest attention from surgeons, both because of the severity of the pain and disability associated with a badly affected hip and because of the relative simplicity of operating on a large ball and socket joint.

The ideal modification or reconstruction must fulfil a number of basic requirements, such as those set out in Table A1. It must first of all be durable. That is, it must be mechanically sound and, in the case of an artificial implant, it should not wear too much or be susceptible to fracture or loosening. Loosening may be caused by maldistribution of stress, by failure of cement to adhere or by the phenomenon of bone resorption which is frequently observed in living bone subjected to alterations in loading after insertion of a prosthesis. The material of an implant must be inert, to avoid reaction with the host tissue. Sterility must be adequate to avoid infection and the consequent removal of the implant. And if removal is unavoidable there must be satisfactory salvage potential. The procedure must of course by clinically effective, in particular offering renewed mobility and relief of pain for a long period

Table A1 *Basic requirements for total joint replacement*

1	Relief of pain
2	Adequate function
3	Correction of deformity
4	Durability
5	Satisfactory salvage potential
6	Chemical passivity
7	Sterility
8	Approximate size to joint
9	Simple operative procedure
10	Minimal operative trauma
11	Early mobilisation
12	Not subcutaneous
13	Universality
14	Reasonable cost

Source Elloy M A (1976). The Basic Requirements and Design Criteria for Total Joint Prosthesis. *Act Orthop Scand*, 47(2), 193–202.

of time. (In the case of osteoarthritis of the hip relief of pain is usually the most important consideration. It probably arises from abnormal stresses produced by the degeneration of tissue.) Finally, it must not be too demanding on medical sources. In this context, early mobilisation is the key criterion.

It was not until the 1960s that total hip replacement for osteoarthritis came acceptably close to fulfilling most if not all of these criteria.

In tracing the development of present day methods of joint replacement this appendix considers the extent to which the requirements were or were not met by succeeding techniques. In doing so it draws heavily on reviews by Scales (1967) and Swanson (1977).

According to Scales, the first successful hip arthroplasty was carried out in 1822. The subject was a nine-year-old boy. The operation involved the removal of the upper end of the femur and the formation of a fibrous union between the remainder of the femur and the pelvis.

Fibrous tissue can be induced, as in a fracture, by removing cartilage and underlying bone and clamping the two raw bone ends together, but then repeatedly moving them in the healing process. An artifical joint formed in this way can give relief of pain with retention of some movement but it is likely to be unstable. A bony union, on the other hand, can be induced, in the same way as bones can be made to knit together after a fracture, by immobilising after clamping. Fusion of the joint in this way is termed arthrodesis. It results in a completely immobile joint. It can, however, completely relieve pain and it remains a common treatment for joints not susceptible to replacement.

The first surgeon to work seriously on artificial materials for repair and replacement of joints was Thomas Gluck in Germany. In lectures during 1890 he described ivory ball and socket joints suitable for the hips. Though screws were apparently required for fixation, Gluck also experimented with bone cements.

Gluck's joints suffered extrusion after some months. In 1926, however, Hey-Groves described a case of non-union of fracture of the femoral head in which the head was removed and replaced with an ivory prosthesis. The patient was active four years later. Scales points out that the ivory head bore a striking resemblance to the Judet acrylic head used 20 years later.

A rather different line of development was initiated in the 1920s by Smith-Petersen of Boston in the USA. (Smith-Petersen 1939). Following an observation that an inert foreign body may, when implanted, induce the formation of a surrounding synovial sac, he reasoned that the interposition of an inert material between a reshaped acetabulum and head of the femur may similarly generate a new articulating surface. He experimented with different materials including celluloid, which caused too great a foreign

body reaction, and glass, which tended to break. But those glass moulds or cups which did not break did indeed generate new cartilage.

In 1938, having had his attention drawn to cobalt-chromium alloy by his dentist, Smith-Petersen inserted a cup of this alloy, vitallium. Results were very encouraging in the first few years but long-term results have been less so. One of the major long-term complications was absorption of the femoral head and shortening of the femur under the mould. Furthermore, less than optimal results were achieved when patients failed to adhere to the recommended post-operative programme of activity, involving crutches for as long as two or three years.

Convalescence of this order made it far from the ideal procedure either clinically or economically. Nevertheless Law (1962), reporting 8–12 year progress in a series of which the majority were primarily osteoarthritic, found good or excellent results in 62 per cent of cases. The great advantage over prosthetic replacement of the hip joint is that mould or cup arthroplasty is a conservative procedure in which the minimum of tissue is destroyed. Thus further reconstructive work can be done if relief of pain is not satisfactory. The risk of failure leading to total loss of the limb is avoided. Being less radical, the method is still used among younger patients.

In the thirties, experimentation continued in the more radical operation of prosthetic replacement in an effort to find a procedure more effective, both in the short and the long term, and one which would not require such long periods of gradual remobilisation. In 1938 Wiles, in London, replaced both the femoral head and the acetabulum with stainless steel components, fixed by screws and bolts, among six patients crippled with Still's disease. These were the first metallic total hip replacements. According to Swanson, however, in the light of present day materials science, it is not surprising that the materials used (having different manufacturing histories and probably different compositions) tended to disintegrate.

In 1946 Jean and Robert Judet in France introduced the Judet acrylic femoral head replacement for treatment of osteoarthritis of the hip, congenital dislocation of the hip and non-union of fractures of the femoral neck. It consisted of a greater than hemispherical head with a straight and relatively short stem through the lateral cortex of the femur below the great trochanter. The natural acetabulum was remodelled to fit as required. Their view was that osteoarthritis is primarily a destructive disease of the femoral head and thus cup arthroplasty as performed by Smith-Petersen and others could not be expected to give consistently good results, the bone being unable to support the cup.

Initial results were impressive. The patient was relieved of pain and mobility of the new joint was good. Furthermore, walking was

usually allowed on the twelfth day after operation, thus greatly enhancing the practicability of treating patients, especially elderly ones, for whom a prolonged period of semi-mobile convalescence was unsatisfactory.

Within a few years, however, failures began to become evident. These were to turn a success story into a cautionary tale of the dangers of too rapid diffusion and ill-considered modification of a not wholly tested innovation.

By the time the English edition of the Judet's early results had appeared loosening and fractures of the stem had begun to occur. So too had evidence of abrasion of the head and adverse reaction with the host tissues. It appears in retrospect that concepts of the forces acting through the head of the femur, implicit in the design of the prosthesis, were rudimentary. Cavalier manufacturing practices did not help. Scales describes how, in an effort to strengthen the acrylic prosthesis, stainless steel rods were incorporated. But they failed to have the desired effect. Sometimes the insertion of the reinforcing rod would cause the acrylic to craze, leaving the rod so loose as to rattle within the prosthesis. Nor were the sometimes bizarre modifications of the prosthesis beneficial to the long-term performance of Judet type implants. And extension of the operation to fresh fractures was criticised by the Judets themselves as representing an illogical sacrifice of a healthy femoral head.

With increasing failures, modifications in the design were made. A cobalt-chromium version was produced which largely overcame fracture and wear problems. But the problem of loosening through bone absorption remained. Eventually the prosthesis fell out of favour with the growing appreciation of its basic material and mechanical design faults. Scales' assessment, in retrospect, was that the Judet procedure was one of the greatest disasters in surgery. But nevertheless, with its remarkable short-term effectiveness in alleviating pain and renewing mobility, it stimulated considerable effort towards the development of a more durable version.

During this time, a significant innovation was made elsewhere. In 1951 Haboush, in New York, inserted a vitallium ball and socket joint in which both the acetabular and the femoral component was fixed with dental acrylic cement. He was the first to use this cement, which has not yet been superseded. (Haboush 1953). The design of the prosthesis did not however serve as a model for future developments.

During the 1940s and 1950s experimentation was continuing in the replacement of the femoral head only, that is partial hip replacement. In fact the periods of development of total and partial hip replacement very largely overlap. Some of the best results were obtained by Moore and Thompson. Moore's record of over 200 operations in America showed no breakages or wearing of the prosthesis and only one case of loosening. But bone resorption and

acetabular migration was a problem and a significant number of patients expressed dissatisfaction over stability. Experience over a number of years indicated that it was worthwhile replacing both femoral head and acetabulum together.

The design which eventually set the scene, in the sense of being widely used and copied, was the total hip replacement developed by McKee in Norwich. By 1956 he had arrived at the basic configuration of a stemmed femoral component articulating in a generally hemispherical acetabular component. Both were made of vitallium. (McKee and Watson-Farrar 1966).

The two steps which together led to the 'take-off' of total hip replacement were introduced by Charnley at Wrightington. First, he followed Haboush in using cold curing acrylic cement to fix both components. Second, he introduced a plastic (high density polythene) acetabular component. Metal/plastic friction characteristics are greatly superior to metal/metal and very considerably enhanced the low friction torque of Charnley's design of a small femoral head articulating against a thick acetabulum. In addition, the plastic component considerably reduces metal wear debris which may be a factor in loosening.

But Charnley's progress towards what turned out to be probably the most successful surgical innovation of recent years was by no means smooth. Before trying high density polythene he had experimented with teflon. This proved to be totally unsuitable and without his insistence on careful evaluation and caution in the diffusion of the technique a repetition of the Judet disaster might have occurred. In the event, polythene has been shown to be inert and durable, the design of the device is mechanically sound and the acrylic cement has given good fixation. The effectiveness of total hip replacement has now been demonstrated in the short and medium term. Quantitative indicators are set out in the section of 'Benefits and Costs'. The only question marks which remain concern performance in the long term. Answers will have to wait until adequate numbers have been followed up over a long enough period. By that time, of course, many elements of earlier operations may have been superseded.

By the mid-sixties hip replacement was a well established operation and the history since then has been one of diffusion and refinement of the technique and continuing refinement of design and materials. Although now a routine procedure, it is demanding in time, technique and precision. Operations carried out today, therefore, rely heavily on the observance of methods rigourously worked out by pioneering teams such as Charnley's. In the early years, indeed, Charnley discouraged use of his techniques by anyone he had not personally instructed.

Nevertheless, as with any other procedure, published results vary widely and results generally are presumably subject to even wider variation. The prime causes of failure are loosening, fracture

of the prosthesis (to a lesser extent) and deep infection. Research is being actively pursued along a number of avenues which could lead to reducing the risk of such failures as well as to improvements in clinical effectiveness. Some are described below. In general, however, such is the present effectiveness of total hip replacement in osteoarthritis that innovators are likely to find it difficult to demonstrate a clear advantage over current practice. In addition, the diffusion of further innovation is likely to be relatively slow, particularly in those countries, including the USA and (imminently) Britain, where procedures have been set up to limit uncontrolled experimentation in the insertion of prostheses.

One line of research is towards better fixation of implants. Improved cements are being sought but none has yet superseded that used in the early sixties. Experimentation also continues on cement free fixation. This may be achieved by the use of porous prosthesis surfaces into which bone may grow. Such a natural union can be expected to be more durable than an artificial one. But a major problem that must be overcome is the need for long periods of immobilisation, expensive in scarce hospital resources, while the bony union forms.

Fixation failure may also arise from stresses due to the rigidity of the metal femoral component. Metal is orders of magnitude more rigid than bone. This together with the possibility of avoiding fracture provides the rationale for a search or an alternative material more biochemically compatible with bone.

Yet another avenue of active research aims at doing away with the large femoral inplant altogether. There is a theoretical possibility that a large implant may lead to bone resorption and consequent loosening. Thus a less radical procedure of replacing the surface of the femoral head alone, together with the acetabulum, may prove to be advantageous in this respect. There is an additional advantage of better salvage potential in the event of failure. Recent work along these lines, in the form of a 'double cup' arthroplasty was originated in Italy at the beginning of the seventies (Amstutz 1977). Clinical trials in a number of countries have still not provided definitive results. But it may be that surface replacements, perhaps with newer materials like (inert) ceramic will eventually take over a large amount of conventional hip replacement.

Failure due to infection may be short term or long term. In the former case it is likely that the infective agent is introduced at the time of the operation. An MRC trial on systems designed to achieve ultra-sterile operating theatre conditions has just been completed. It concludes that they can have a substantial effect on post-operative infection rates.

In the case of long-term infection it is likely that the implant provides a focus for any systemic infection in the implantee. Thus research aimed at reducing failure attributable to this cause encompasses the impregnation of cement with antibiotics and the

search for more biocompatible materials to minimise local host/implant reactions which may increase susceptibility to infection.

Knees

Pioneering efforts at knee replacement were started about the same time as hip replacements. With the success of hip implants interest was renewed in knees but the problem has been more difficult with the inherent complexity of the joint. The earliest designs were simple hinges. These allow flexion/extension in a single plane. Sideways movement and rotation are prohibited and this not only limits the functioning of the joint but also involves transmission of forces (leading to loosening or possible fracture) which the natural knee joint, with its greater degrees of freedom, does not. This led to the design of 'unlinked surface replacements'. In these the femoral and tibial components are relatively free to move and rotate with respect to each other. Thus the range of function is better and the limitation of forces transmitted through the joint renders the loosening problem less acute. However, the disadvantage is that such knees can be dislocated and they rely for their effectiveness on intact ligaments and other soft tissues. These are presently the commonest type in use.

Active research continues, but a number of the basic requirements for joint replacement, set out in Table A1 are likely to be difficult to meet. Knee replacement is a difficult operation, requiring more complex instrumentation. The implant is inevitably subcutaneous and clinical effectiveness comparable with hip replacement has as yet proved elusive.

Other joints

The elbow, like the knee, is primarily a hinge type of joint and implants have suffered from the same design problems. The limitation of movement to one plane is particularly restricting. Some unlinked surface designs are now being tried.

For the wrist and ankle, ball and socket implants have been employed but creation of a socket in the scapula is difficult. For this reason some designers have reversed the natural order of attaching a ball to the scapula and creating a socket in the humeral component. Finally finger joints have been replaced by implants of both the constrained hinge and the non-linked type. Problems remain in reducing the risks of both dislocation and loosening to acceptable levels at the same time.

Appendix 2

Annual incidence of new cases of osteoarthritis of the hip, according to given diagnostic criteria, are calculated from prevalence data on the basis of three assumptions:

- that the prevalence of osteoarthritis, operated or otherwise, is in an approximately steady state within each age group in an approximately stable population structure.
- that mortality rates among persons with osteoarthritis do not differ significantly from age specific mortality rates for the population as a whole.
- that there is no significant remission from osteoarthritis of the hip which has reached a level of severity such as to justify surgery.

It is known that the first condition is only approximately true, but for the purposes of the exercise the approximation is adequate. Given this, it may be deduced that numbers entering the set of persons at or above a given threshold level will be balanced by numbers leaving the set. Since remission is assumed to be zero, the only ways of leaving the set are death and ageing. (Operation is excluded as a means of exit since either the data used refer to periods before effective surgical intervention was possible or, as in Wilcock's data, operated persons are counted in the prevalence data). Thus the number of cases in a given age group reaching the threshold level each year (incidence) can be equated with the number of existing cases dying or entering a different age group.

This can be expressed as:

$$INC(i \text{ to } j) = [PREV(i \text{ to } j) \times (POP(i \text{ to } j)) \times (MORT(i \text{ to } j))] + [PREV(j) \times (POP(j))] - [PREV(i-1) \times (POP(i-1))]$$

where

INC = Incidence (number) of cases reaching a given threshold of suitability for operation.

PREV = prevalence per unit population.

i and j (years of age) are the limits of the age band considered.

POP = population in the given age band or single year of age.

MORT = Mortality rate per unit population in the given age band.

The resulting incidence estimates are more robust for the younger (45–64) age group. Doubling the mortality rate assumed for arthritics increases the incidence estimate by about 30 per cent. Replacing Danielsson's prevalence rates with their estimated limits, derived from the square roots of the relevant sample numbers, increases the incidence estimate by less than 10 per cent.

For the older (65+) age group, doubling the assumed mortality rate increases incidence about two and a half times. Replacing Wilcock's prevalence rate with an upper limit, derived by adding the square root of the number of cases sampled, increases the incidence estimate by about two-thirds.

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