Evaluating the Cost-Effectiveness of Fall Prevention Programs that Reduce Fall-Related Hip Fractures in Older Adults

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OBJECTIVES: To model the incremental cost-utility of seven interventions reported as effective for preventing falls in older adults.

DESIGN: Mathematical epidemiological model populated by data based on direct clinical experience and a critical review of the literature.

SETTING: Model represents population level interventions.

PARTICIPANTS: No human subjects were involved in the study.

MEASUREMENS: The last Cochrane database review and meta-analyses of randomized controlled trials categorized effective fall-prevention interventions into seven groups: medical management (withdrawal) of psychotropics, group tai chi, vitamin D supplementation, muscle and balance exercises, home modifications, multifactorial individualized programs for all elderly people, and multifactorial individualized treatments for high-risk frail elderly people. Fall-related hip fracture incidence was obtained from the literature. Salary figures for health professionals were based on Bureau of Labor Statistics data. Using an integrated healthcare system perspective, healthcare costs were estimated based on practice and studies on falls in older adults. Base case incremental cost utility ratios were calculated, and probabilistic sensitivity analyses were conducted.

RESULTS: Medical management of psychotropics and group tai chi were the least-costly, most-effective options, but they were also the least studied. Excluding these interventions, the least-expensive, most-effective options are vitamin D supplementation and home modifications. Vitamin D supplementation costs less than home modifications, but home modifications cost only $14,794/quality-adjusted life year (QALY) gained more than vitamin D. In probabilistic sensitivity analyses excluding management of psychotropics and tai chi, home modification is most likely to have the highest economic benefit when QALYs are valued at $50,000 or $100,000.

CONCLUSION: Of single interventions studied, management of psychotropics and tai chi reduces costs the most. Of more-studied interventions, home modifications provide the best value. These results must be interpreted in the context of the multifactorial nature of falls. **J Am Geriatr Soc 58:136–141, 2010.**

Key words: fall prevention; fall interventions; cost-utility; cost-effectiveness

Approximately one-third of adults aged 65 and older and half of those aged 80 and older fall at least once per year.[1] With more than 35 million older individuals in the United States,[2] it is estimated that approximately 12 million fall each year and that 2.6 million need medical attention.[3] Thus, fall prevention represents an important opportunity for ameliorating morbidity and mortality in older adults.

Despite substantial research on fall prevention interventions, there is scant evidence regarding the relative cost-effectiveness of different strategies.[4] The dearth of such studies may result from the heterogeneity of fall victims and types of falls, the heterogeneity of treatment costs, or from the lack of funding for large-scale, longitudinal studies of varied interventions. A cost-effectiveness analysis of fall prevention programs would help integrated healthcare systems, which are at risk for incurring lifetime costs, to allocate resources efficiently. The current study combined results from the existing literature to evaluate which are the most cost-effective interventions and suggest directions for additional research.

METHODS

Perspective and Time Horizon

The perspective of an integrated healthcare system, in which annual program costs, lifetime healthcare and care

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DOI: 10.1111/j.1532-5415.2009.02575.x

0002-8614/10/$15.00

costs, and quality-adjusted life years (QALYs) related to hip fractures are included under one integrated system, was used.

Model

The principal outcome was the prevention of falls. The decrease in falls was assumed to be related linearly to a decrease in the number of fall-related hip fractures. The change in the number of falls in the year of a preventive intervention was translated into health system costs averted and QALYs gained over the target population's remaining lifetime. The model was populated using data on the quantity of personnel needed to administer the interventions (based on direct clinical experience and a critical review of the literature), varying probabilities of falls, the estimated costs of caring for individuals who have fractured hips as a result of falls, and the estimated QALYs lost to hip fractures.

Incidence of Fall-Related Hip Fractures

Studies that report on fall-related hip fracture are largely restricted to elderly women or institutionalized older people.[5] Several data sources were combined to estimate the percentage of fallers in community-dwelling adults aged 65 and older who experience hip fractures. The fraction was calculated by dividing the estimated annual number of fall-related hip fractures by the total annual number of fallers aged 65 and older. Previously reported data indicate that, of the approximately 300,000 hip fractures reported annually in the United States,[6] 165,600 (55.2%) result from reported falls.[7] An additional 23.9% of all hip fractures are attributed to unknown causes; these are probably the result of unrecorded falls. Including these unexplained hip fractures, the percentage of all fallers aged 65 and older estimated to sustain a hip fracture is 2.0%. In the probabilistic sensitivity analyses, it was assumed that the distribution of the proportion was normal and had a standard deviation that was 25% of the point estimate.

QALYs Lost to Hip Fractures

Health utility is a health-related quality-of-life measure for which the value is determined by a willingness to accept a risk of death or give up years of life to live in perfect health rather than a hypothetical nonoptimal health state. Measures of these levels are an input for QALY calculations. To calculate the health utility of those who do not fall, data were used from a study that employed a simulation model to estimate the health utilities in each age segment of older adults (50–64, 65–74, 75–84, and $\geq$85), comparing the general population with individuals who had experienced a hip fracture.[8] Based on these data and U.S. Census data indicating the number of individuals in each age group, the average health utility of a nonfaller was calculated to be 0.8232 (on a scale from 0 to 1 where 0 is the same as death and 1 is perfect health). For probabilistic sensitivity analyses, it was assumed that the health utility was taken from a normal distribution with a standard deviation of 0.025.

To account for annual QALYs that result from living and the lack of QALYs that result from dying, for fallers who died in the first year, 0.8232 QALYs (the average health utility for a nonfaller) were deducted in each year for the remainder of their life expectancy (9 years). The portion who died in the first year is based on another study that reported that of subjects aged 65 and older who sustained a hip fracture, 36% died within 1 year.[9] In probabilistic sensitivity analyses, it was assumed that the 64% 1-year survival rate was taken from a normal distribution with a standard deviation of 0.02.

Fallers who survived the first year were assumed to lose 0.20 QALYs in the first year[8] and 0.06 QALYs in each year after the first year. The latter is based on a study that evaluated the disability and distress state of 1,400 patients with hip fracture using the Rosser evaluation matrix and reported a health utility score of 0.94. This study also indicated that the life expectancy for fall survivors decreased from 9 to 7.2 years.[9] In the probabilistic sensitivity analyses, the loss of 1.8 years of life expectancy was not varied, but the loss of utility after the first year was varied, with a normal distribution and standard deviation of 0.01.

All QALY calculations used a 3% discount rate to calculate the present value after the first year, as recommended by the U.S. Panel on Cost-Effectiveness in Health and Medicine.[10]

Healthcare Costs Associated with Hip Fractures

The analyses assumed that costs related to hip fracture are in addition to any costs incurred for existing conditions that do not change with a hip fracture. Data on the costs were drawn only from cost studies conducted in the United States. The costs were adjusted for medical care inflation for 1998 to 2007 and general economic inflation rate before 1998.[11,12] Inflation-adjusted first-year societal hip fracture costs averaged from three studies were \$58,120 $\pm$ 14,185. The present value of lifetime costs was estimated to be \$86,967 $\pm$ 21,225 based on the finding that first-year costs represent 45% of total lifetime costs, a 3% discount rate, and 7.2 years of life expectancy.[13–15]

Fall Prevention Interventions

A 2003 Cochrane database analysis of randomized controlled trials of fall prevention programs in elderly individuals reported relative risk ratios along with 95% confidence intervals.[16] Although 2004 and 2007 meta-analyses also exist, the Cochrane database analysis was chosen for this article, because it is more thorough in its search methodologies. Because the Cochrane data for fall prevention programs were from 2003 and earlier, the findings were supplemented with more-recent studies in the discussion.

The seven alternatives to be compared with standard care are:

(1) Individualized multifactorial population-based approach for elderly people in general (4 trials, N = 1,651)
(2) Individualized multifactorial approach for high-risk elderly people or those who had fallen in the previous year (5 trials, N = 1,176)
(3) Home modifications for high-risk elderly people: occupational therapists, physical therapists, and nurses recommending removal of hazards in the home (3 trials, N = 374)
(4) Vitamin D supplementation: taking 800 IU or more of vitamin D per day (3 trials, N = 5,572)

Table 1. Data for Modeled Interventions

Intervention	Average Labor Hours Needed to Implement Intervention Annually							Cost (2007$)	Meta-Analytical Results Relative Risk (95% Confidence Interval)
	Physician	Nurse	Exercise	Physical Therapist	Occupational Therapist	Social Worker	Pharmacist		
Multifactorial, all elderly people	0.37	1.63	0.50	0	0.01	4.63	0.13	272	0.73 (0.63–0.85)
Multifactorial, high-risk elderly people	1.00	3.27	0	0	0.40	0	0	361	0.86 (0.76–0.98)
Muscle balance training	0	0.67	0	5.00	0	0	0	371	0.80 (0.66–0.98)
Home modifications	0	1.83	0	1.17	2.33	0	0	326	0.66 (0.54–0.81)
Psychotropic withdrawal	0.5	1.50	0	0	0	0	0	160	0.34 (0.16–0.74)
Tai chi	0	0	2.50	0	0	0	0	104	0.51 (0.36–0.73)
Vitamin D supplementation	0.5	0	0	0	0	0	0	99	0.74 (0.61–0.88

(5) Medical management of central nervous system drugs, particularly the withdrawal of psychotropics such as benzodiazepines, antidepressants, and antipsychotics (1 trial, N = 93)
(6) Muscle/balance training (3 trials, N = 566)
(7) Tai chi (1 trial, N = 200)

Point estimates and the bounds of 95% confidence intervals for relative risks are shown in Table 1. Standard care was assumed to consist of a standard medical evaluation that defines the baseline level of health and routine examinations and treatments needed.

Calcium, hip protectors, and health visitors were not included in the analyses. A recent meta-analysis of calcium studies found calcium to be ineffective in reducing the incidence of falls.[17] Moreover, a large study of hip protectors was so unsuccessful that it was discontinued.[18] Health visitors and education had the same insignificant effect.[19]

Costs of Fall Prevention Interventions

To estimate the costs behind these interventions, the number of necessary direct labor hours were multiplied by the market wages of the necessary types of professionals, and the cost estimates were adjusted upward by 30% to account for employee benefits and another 50% to account for overhead (e.g., office space, administrative costs). The number of direct labor hours expended was calculated for each evaluated intervention, using 2 hours as the assumption for a first visit, including transportation time, and 1.5 hours for any subsequent visits. The exceptions are physicians and mental health nurses, who it was assumed that the patients visit based on clinical experience with best practices. Salaries were derived from Bureau of Labor Statistics data (http://www.bls.gov), with the American Medical Association (http://www.ama-assn.org) and the national Internet wage resource http://www.salary.com serving as second references. Estimates of clinical work time needed by each staff member were used. The annual number of hours needed per participant to implement each intervention and the total cost (wages, benefits, and overhead) are shown in Table 1.

Incremental Cost-Effectiveness and Sensitivity Analysis

A base case incremental cost-effectiveness analysis and a probabilistic sensitivity analysis were conducted. The distributions and standard deviations of the distributions for the parameters other than relative risk were described above. The logarithm of the relative risk was assumed to be distributed normally, and the confidence intervals were used to infer the standard deviations. The simulation was replicated 100,000 times with random draws from all distributions. The results are reported as a cost-effectiveness acceptability curve indicating the proportion of replications for which each of the interventions has the highest net benefit at dollar values of a QALY ranging from $0 to $200,000 in $1,000 increments.

RESULTS

Figure 1 shows the results of the base case incremental cost-effectiveness analysis. Along the horizontal axis, the QALY gains compared with standard care are measured. Along the vertical axis, the expected cost of 1 year of intervention and the care for any falls that occur is measured. Medication management of psychotropics is the least expensive and most effective (lowest on the vertical axis and furthest to the right on the horizontal axis), but management of withdrawal from psychotropics may be difficult to sustain.[20] In other interventions studied, tai chi was found to be the least expensive and most effective, although in the Cochrane database review, tai chi was included as a randomized trial only once. In one later study involving 291 frail and transitional elderly people, tai chi did not seem to reduce the relative risk of falling in transitionally frail, older adults, but in another randomized controlled trial, tai chi seemed to significantly reduce the number of falls as well as the number of injurious falls.[21,22] (Neither study was included in the Cochrane review.)

Of the six other alternatives, only vitamin D supplementation and home modification were the least expensive and most effective. Of these two, vitamin D supplementation was less expensive, and home modifications were more effective. Because the other four alternatives are more expensive and less effective than vitamin D supplementation, home modification, or both, they are not discussed further except in the sensitivity analysis. This is a modeling decision, not necessarily a policy decision. Vitamin D supplementation and home modification are both less expensive than the current standard of care, but vitamin D supplementation saves more than home modification, although home modification is a more-effective and relatively

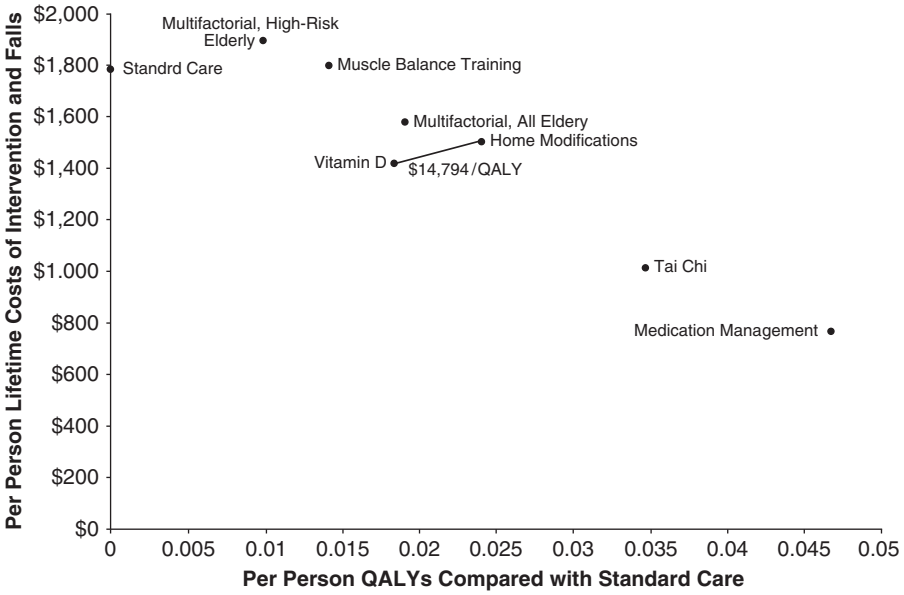

Figure 1. Incremental cost-effectiveness of fall prevention interventions. This figure shows the per-person lifetime costs associated with prevention and falls for seven interventions and standard care and the quality adjusted life years (QALYs) to be gained by the seven interventions over standard care. Medication management is associated with the lowest per-person lifetime cost and the largest gain in QALY over standard care. Considering only those interventions, with the substantial data supporting the conclusions, home modifications yields the greatest gain in QALYs but is slightly more expensive than vitamin D supplementation. The slope of the line connecting the points representing the cost and QALY results related to vitamin D supplementation and home modifications is $14,794 spent per QALY increased, which is considered a good buy in the United States.

cost-effective intervention, costing only $14,794/QALY more than vitamin D supplementation.

Figure 2 shows the results of the probabilistic sensitivity analysis. The vertical axis ranges from 0% to 100%, representing 100% of the repeated simulations. The 100% is divided into sections based on the proportion of the 100,000 simulations for which each of the alternatives being considered had the largest positive economic net benefit. The interventions other than vitamin D supplementation and home modification combined were never the economically most preferable option in more than 4% of all repeated simulations at any dollar value of a QALY. Furthermore, if the focus were only on cost savings (i.e., valuing QALYs at 0), vitamin D supplementation would be most likely to have the highest net benefit. At $50,000/QALY, home modification had the highest net benefit in 54.1% of the replications, and vitamin D supplementation had the highest net benefit in 29.7% of the replications. At $100,000/QALY, home modification had the highest net benefit in 59.3% of the replications, and vitamin D supplementation had the highest net benefit in only 23.0% of the replications. At the maximum dollar value considered ($200,000/QALY), the dominance of home modification was even greater; 62.6% of the replications were consistent with home modification having the highest net benefit, and only 19.0% were consistent with vitamin D supplementation having the highest net benefit.

DISCUSSION

If management of psychotropic medications (particularly withdrawal of such medications) is sustainable, it is by far the most effective and least expensive falls management option of those considered, and it would be less expensive than the standard of care. Group tai chi classes may also result in substantial cost savings and fall risk reduction if they are sustainable. The ongoing cost of classes or the potential for attrition would probably diminish the relative advantage of group tai chi classes.

If neither of those two were as effective and cost saving as the model suggests, decision makers could consider vitamin D supplementation, which is less expensive and improves health more than standard care. Although vitamin D saves more money than home modifications, home modifications provide a good value for money spent. Although several studies have shown significant reductions in hip fractures when vitamin D is taken at 800 IU/d or more[23] and the high prevalence of vitamin D deficiency in community-dwelling elderly people (40–100%), the relative cost-utility of a highly targeted intervention such as vitamin D supplementation is likely to be limited to cases marked by marginal or low vitamin D levels. Home modification has a greater level of likely sustainability than vitamin D, tai chi, and psychotropic management.

Better fall prevention will occur only when steps are taken at the organizational and policy level, as well as at the level of the individual patient. At the organizational level, more work is needed to evaluate the comparative effectiveness of specific interventions as applied to adequately qualified cohorts of patients by individual practitioners or teams of practitioners. At the systems (i.e., policy) level, more work is needed to refine the standardization of the methodology and metrics in use by diverse investigators to enable enhanced comparability across studies over time.

Although the choice of the most-preferred intervention depends on the exact criteria used, the combination of

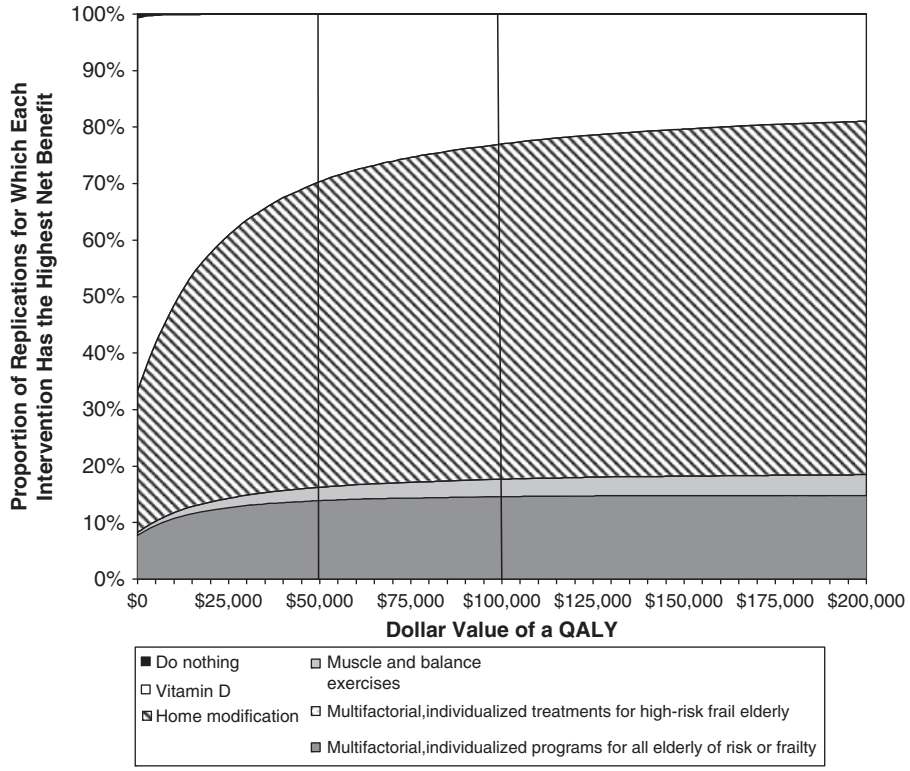

Figure 2. Probabilistic sensitivity analysis. This graph displays a summary of the results from 100,000 simulations. For each simulation, the parameters were based on random values drawn from distributions defined in the Methods section of the text. Because the monetary value of a quality of life adjusted year (QALY) for a decision-maker is unknown, varying values were applied to a QALY, from $0 to $200,000. At each dollar value, the graph displays the proportion of the 100,000 simulations for which each of the six choices for fall prevention had the highest net benefit (converting the resulting QALYs into a monetary figure and subtracting the cost of the intervention and care for falls). When a QALY is given no value, suggesting that the decision-maker cares only about costs, vitamin D is most likely to have the highest net benefit (be cost saving); the largest fraction of the vertical line at $0 is white. When a QALY is given a value of $200,000, home modifications are most likely to have the highest net benefit; the largest fraction of the vertical line at $200,000 is cross-hatched.

effectiveness and cost data suggest that several interventions can be eliminated. First, remaining with standard care (defined as routine, individualized medical evaluation and care) is unacceptable. Thus, future comparative effectiveness studies, guidelines, and policy recommendations should focus on appropriate medication management, tai chi, home modification, and vitamin D supplementation. It is important to note when considering the option of supplementation or medication management that falls prevention is not necessarily the only or even primary effect intended by the prescribing practitioner. Thus, further consideration needs to be given to an understanding of all benefits for either of these two interventions to perform an effective cost-effectiveness analysis and to the multifactorial nature of falls.

The model-based results reported here reflect the findings of other recent studies—that multifactorial approaches (the multifactorial interventions aimed at all elderly people or high-risk elderly people) are not necessarily more cost-effective or better than focused intervention approaches.[24,25] Any multifactorial intervention will be more expensive than an intervention involving only one facet. The key from an economic standpoint is whether observed incremental and possibly synergistic gains in clinical outcomes outweigh the inherent incremental costs of multifactorial interventions over more efficiently mounted and applied interventions (e.g., medication management and supplementation).

Future studies can focus on whether there are other opportunities for synergistic effects of multiple interventions that can be combined. Such analyses were not conducted in the current study, because there is little evidence to suggest that the costs or effects are anything other than simply additive. Future studies can assess the effectiveness of and resources needed to implement combined programs. The interventions that were found to be potentially among the most cost-effective based on this analysis deserve further consideration as parts of overall plans.

The primary limitation of this study is that it was based on secondary and not primary research. One of the many implications of this type of study design is that the interventions, although comparable, have results that may depend on the design of the intervention and the comparison groups. The included meta-analyses report an uneven number of studies per intervention alternative, with variability in the number and health status severity of the adults participating in these studies. The probabilistic sensitivity analysis provides insight into how the variability of the point estimates of effectiveness and numerous other parameters in the model effect the outcomes. Although no alternative is completely dominant, vitamin D supplementation and home modifications together are dominant in

80% of the replications of the simulation regardless of the dollar value of a QALY.

Another limitation of this study is the inability to compare cohort effects according to risk status. One category of the multifactorial approach and home modifications have been studied for high-risk elderly people. The other four interventional categories (medication management, tai chi, muscle and balance training, and vitamin D supplementation) were ostensibly not risk-stratified.

A third limitation is that the analyses are based on published studies that peer reviewers typically selected based on their report of statistically significant effects. Other, less-salutary efforts typically go unpublished.

Finally, the analyses that were done focused on single interventions separately. Even without data, many organizations will implement several programs in an overlapping or sequential fashion, with potentially low fidelity. As a result, the results of this study should be viewed as instructive for future decision-making, but individual organizations making decisions about implementation will need to consider how closely their costs and implementation match the models.

In conclusion, this work, as well as the findings of studies published after 2003, suggests that future research efforts should focus on home modifications, vitamin D supplementation, group tai chi classes, and medication management.[22,26–29] More (and better) information on each of these and combinations of these will make it easier to make more-efficient resource allocation decisions in the future. The potential for large cost savings over standard care cannot be ignored given the number of older adults, the coming Medicare resource limitations, and the aging of the population.

ACKNOWLEDGMENTS

Conflict of Interest: The editor in chief has reviewed the conflict of interest checklist provided by the authors and has determined that the authors have no financial or any other kind of personal conflicts with this paper.

Jacquelyn Y. Kung is consultant to the senior housing and services industry (usually strategy, marketing, and new entry product projects) including for affiliates of Erickson Retirement Communities.

Author Contributions: Kevin D. Frick: concept and design, analysis and interpretation of data, preparation of manuscript. Jacquelyn Y. Kung: design and methodology, editing of manuscript, literature search, discovery of secondary data used. John M. Parrish: interpretation of data, preparation of manuscript. Matthew J. Narrett: manuscript editing and making of suggestions based upon clinical perspective and fund of knowledge.

Sponsor's Role: The Erickson Foundation was not an official sponsor of this research, although it is pleased to be a contributor to it.

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