COMORBIDITIES IN COST BENEFIT ANALYSES OF HEALTH CARE

by

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Abstract

The aim of this paper is to examine the dependency of the benefits of health improvements on comorbid conditions. We find that under plausible conditions regarding the utility function over wealth and health, the willingness to pay for health improvements increases with the severity of the comorbid conditions. This positive relationship between willingness to pay and severity of comorbid conditions has implications both for the empirical elicitation of willingness to pay measures and for applications of cost benefit analysis in health policy.

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JEL CLASSIFICATION : D61, D81, I10

Many social scientists express doubts about the relevance of cost benefit analyses (CBA) in the field of health because the willingness to pay concept which is at the root of the measurement of benefits tends to favor young patients at the expense of old ones.

Although this suspicion is to a wide extent justified, we show in this paper that it needs to be qualified once comorbidities are taken into consideration. We essentially obtain that under plausible assumptions the existence of health problems other than those of the index condition that is being treated do increase the monetary benefit attached to the treatment. Since old people are also more likely to face multiple health troubles, the positive effect of comorbidities on the treatment value will to some extent compensate for the negative impact of age.

Surprisingly the topics of comorbidities is very new in health economics. In a quite recent contribution, HARRIS R. and R. NEASE (1997) (henceforth H-N) have pointed out that many cost-effectiveness studies in the field of health have neglected to « *account for the morbid conditions that patients experience other than the index condition being studied* ». In their note they show how comorbid conditions affect the estimation of the number of quality adjusted life years (QALY's) gained from a therapeutic decision. Their main conclusion is that « *analyses that ignore comorbidities overstate an intervention's health benefit relative to analyses that do account for comorbidities* ».

H-N have raised an important question that was too often neglected both in theoretical and applied studies. The purpose of the present paper is to extend their contribution in two directions.

First, instead of looking at the impact of comorbidities for cost-effectiveness studies (hence H-N's interest in QALY's) we consider their impact on willingness to pay measures which are more directly relevant for cost-benefit analyses. Examining W.T.P. forces us to introduce a two dimensional utility function (of health and of wealth) which raises specific technical difficulties not present in H-N's paper.

Second, while H-N consider only existing comorbidities, we also examine the impact of potential comorbidities that might develop in the future along with the evolution of the index condition being studied. In this way we create a bridge with the recent economics literature on background risks as applied to saving or insurance decisions [KIMBALL (1990), EECKHOUDT-KIMBALL (1992)]. We generalize the latter approach by studying the impact of background risks in decision problems involving two-dimensional utility functions.

The paper is organized as follows. The general model is presented in section 1. We consider the willingness to pay (W.T.P.) of a patient for improvements in his health conditions towards a specific illness (the « index condition ») while he may or may not also develop another illness (the « comorbidity risk »).

In section 2, we analyze the properties of two W.T.P. concepts[1] with regard to the severity of the comorbid condition, assuming – as in H-N – that this condition is present with certainty.

Section 3 extends the analysis to the case of a random comorbidity while in section 4 attention is paid to the impact of mean preserving changes in risk related to the comorbid condition.

[1] The two concepts are the W.T.P. to reduce the probability of occurrence of the index condition and the W.T.P. to reduce the severity of the index condition if it were to occur (see below).

Our main conclusion, presented in section 5, is that the impact of comorbidity on W.T.P. critically depends upon properties of the two dimensional utility function (of wealth and health) that is used to define W.T.P. Under the most plausible assumptions, comorbidity increases W.T.P. for actions that improve the patient's position towards the index condition. Thus analyses that fail to consider comorbidity underestimate W.T.P. This result is important for cost-benefit analysis For instance it is often claimed that because W.T.P. falls with age, application of cost-benefit analysis would lead to health policies that are detrimental for old people. However, in a recent study of comorbidity factors among unselected cancer patients in the Netherlands over the period 93-96, J.W.W. COEBERGH et al (1999) found that comorbid conditions were present in 12% of adult cancer patients below 45 years of age, 28% of those 45-59 years, 53% of those 60-74 years and 63% of patients over 75 years of age. Hence there is clearly an increase of comorbidity risk with age and thus consideration of comorbidity in CBA compensates at least partially for the age effect.

1. The general model

We consider an individual who derives utility from his wealth (W) and his health (H), so that

$$U = U(W, H) \tag{1.1}$$

We adopt for U standard assumptions :

- U_1 and U_2, the marginal utilities with respect to each argument are strictly positive ;
- U_{11} and U_{22} are negative so that the individual is risk averse towards a single risk on each argument of U ;
- U_{12} the cross second derivative of U is assumed non negative (quote references). Further assumptions on higher order derivatives will be made when necessary.

Full health which is denoted H_0 is threatened by two illnesses (1 and 2) the severities of which are denoted respectively M_1 and M_2. The probabilities of occurrence are p_1 and p_2 and the two risks are independent. Consequently there are four possible states of the world :

$$\begin{aligned}
&H_0 \text{ with probability } (1-p_1)(1-p_2)\\
&H_0 - M_1 \text{ with probability } p_1(1-p_2)\\
&H_0 - M_2 \text{ with probability } (1-p_1)p_2\\
&H_0 - M_1 - M_2 \text{ with probability } p_1 p_2
\end{aligned} \tag{1.2}$$

Implicit in (1.2) is the assumption that the severities are additive when the two diseases occur simultaneously.

In this framework, the patient's initial expected utility is :

$$E[U] = p_1 p_2 U(W, H_0 - M_1 - M_2) + p_1(1-p_2)U(W, H_0 - M_1)$$

$$+(1-p_1)p_2 U(W, H_0 - M_2) + (1-p_1)(1-p_2)U(W, H_0) \qquad (1.3)$$

For notational convenience, we define :

$$\begin{aligned} H_{12} &\equiv H_0 - M_1 - M_2 \\ H_1 &\equiv H_0 - M_1 \\ H_2 &\equiv H_0 - M_2 \end{aligned}$$

In the rest of the paper disease 1 will be the index condition and disease 2 the comorbid one.

Given (1.3) two W.T.P. concepts can be developed for the index condition :

- how much wealth is the patient willing to give up in oder to reduce p_1 from its baseline level ;
- how much wealth is the patient willing to give up in order to reduce the severity of illness 1 (M_1) from its baseline level.

Formal expressions for these two W.T.P. concepts can be obtained by differentiating (1.3) with respect to p_1 and M_1, to yield[2] :

$$\frac{dW}{dp_1} = \frac{-[p_2 U(W, H_{12}) + (1-p_2)U(W, H_1)] + [p_2 U(W, H_2) + (1-p_2)U(W, H_0)]}{p_1[p_2 U_1(W, H_{12}) + (1-p_2)U_1(W, H_1)] + (1-p_1)[p_2 U_1(W, H_2) + (1-p_2)U_1(W, H_0)]} \qquad (1.4)$$

$$= \frac{M}{N} \text{ for short}$$

Notice that : $M > 0$ because $U_2 > 0$
$N > 0$ because $U_1 > 0$

so that $\frac{dW}{dp_1}$ is positive : an increase in p_1 should be compensated for by an increase in W.

Similarly,

$$\frac{dW}{dM_1} = \frac{p_1[p_2 U_2(W, H_{12}) + (1-p_2)U_2(W, H_1)]}{N} \qquad (1.5)$$

$$= \frac{\hat{M}}{N} \text{ for notational convenience}$$

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[2] The detailed procedure is illustrated in appendix 1 for the case of a change in p_1. Let us also notice that the W.T.P. concept was defined in different ways in the literature. For instance, using an indirect utility function, P.O. JOHANSSON (1995) defines a « W.T.P. locus » (see especially his chapter 4 « Money measures in a risky world »). An interesting presentation can also be found in ZWEIFEL P. and F. BREYER (1997), especially in chapter 2, section 2.3 « Monetary evaluation of the length of life ».

$\hat{M}$ being positive, an increase in M_1 must be compensated for by an increase in W. In fact $\frac{dW}{dM_1}$ measures willingness to pay to reduce the severity of illness 1 while $\frac{dW}{dp_1}$ measures W.T.P. to reduce the probability of illness 1. Although a fall in p_1 or in M_1 represent each a first-order stochastic-dominant (F.S.D.) improvement in the patient's health[3] they induce different W.T.P.'s.

Quite interestingly, if $M_2 = 0$ or if $p_2 = 0$ and if H_1 stands for death, then (1.4) reduces to the value of a statistical life (VSL) concept developed by DREZE (1962) and JONES-LEE (1974) (as well as many others thereafter) who considered W.T.P. for a reduction in the probability of death in the absence of any other risk[4]. Indeed for $M_2 = 0$ and $p_2 = 1$ (1.4) becomes :

$$\frac{dW}{dp_1} = \frac{-U(W,H_1) + U(W,H_0)}{p_1 U_1(W,H_1) + (1-p_1) U_1(H_0)} \tag{1.6}$$

Taking H_1 as the state of death (disease 1 implying death) and H_0 as the state of life then the transformation of (1.4) into (1.6) leads to the VSL concept. The severity element which is important only in the present model is irrelevant in the literature on the VSL because attention is focused only on the probability of death.

Let us also mention that a model similar to that presented in (1.3) was already developed by VISCUSI K., W. MAGAT and J. HUBER as early as in 1987 (see also more recently O'CONOR and BLOMQUIST (1997)). However the questions these authors raised were to a wide extent different from those analyzed here. Besides some theoretical concepts (such as that of prudence used here [see below]) were not known at the time the VISCUSI et al paper was written.

In the next two sections we examine the impact of comorbidity (disease 2) on the two W.T.P. concepts defined in (1.4) and (1.5). We proceed in two steps. First, as in H-N, we assume that comorbidity is already present for sure when improvements towards the index condition (disease 1) are being considered. This amounts to using $p_2 = 1$ while M_2 is strictly positive. In the next section and in complement to H-N's analysis, we consider that the comorbid condition is also random $(0 < p_2 < 1 \text{ and } M_2 > 0)$. In each section we wonder how and in which direction the comorbidity affects each W.T.P. which is an important ingredient for any cost-benefit analysis (see e.g. PAULY M. (1995)).

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[3] F.S.D. improvements are changes in the density of a random variables that are unanimously approved by all decision makers with an increasing utility function. Of course all patients who prefer more health to less are unanimous to like either a fall in p_1 or a decrease in severity.

[4] For the sake of completeness let us mention however that in a recent paper L. EECKHOUDT and J. HAMMITT investigate the impact of background risks on the value of a statistical life (VSL).

2. Comorbidity for certain

Let us now turn to the case where comorbidity is certain, i.e. the patient has disease 2 for sure. Note that this means that the index condition and the comorbid one are not treated symmetrically : while disease 1 is only potential, disease 2 is always present. We derive the impact of the introduction of the comorbidity on the two W.T.P. concepts defined in section 1. That is, we examine the impact of the introduction of the comorbidity on the W.T.P. for actions that reduce p_1 or M_1.

When disease 2 is certain, (1.4) and (1.5) become much simpler and can be written as :

$$\frac{dW}{dp_1}=\frac{-U(W,H_{12})+U(W,H_2)}{p_1U_1(W,H_{12})+(1-p_1)U_1(W,H_2)}=\frac{M'}{N'} \tag{2.1}$$

and

$$\frac{dW}{dM_1}=\frac{p_1U_2(W,H_{12})}{p_1U_1(W,H_{12})+(1-p_1)U_1(W,H_2)}=\frac{M''}{N'} \tag{2.2}$$

where M', M'' and N' are positive numbers.

To express the impact of M_2 on each of these expressions, we differentiate (2.1) and (2.2) with respect to M_2 and we obtain :

$$\frac{\partial}{\partial M_2}\left(\frac{dW}{dp_1}\right)=\frac{N'.\left(U_2(W,H_{12})-U_2(W,H_2)\right)-M'\left(-p_1U_{12}(W,H_{12})-(1-p_1)U_{12}(W,H_2)\right)}{\left(N'\right)^2} \tag{2.3}$$

$$\frac{\partial}{\partial M_2}\left(\frac{dW}{dM_1}\right)=\frac{N'\left(-p_1U_{22}(W,H_{12})\right)-M''\left(-p_1U_{12}(W,H_{12})-(1-p_1)U_{12}(W,H_2)\right)}{\left(N'\right)^2} \tag{2.4}$$

Because $U_{22}<0$, the sign of (2.3) and (2.4) depends critically on that of U_{12}. Given our assumption that $U_{12}>0$, both $\frac{\partial}{\partial M_2}\left(\frac{dW}{dp_1}\right)$ and $\frac{\partial}{\partial M_2}\left(\frac{dW}{dM_1}\right)$ are positive (note that this also holds if $U_{12}=0$). Ceteris paribus, an increase in the severity of the comorbid condition increases both the W.T.P. for a reduction in p_1 and the W.T.P. for a reduction in M_1. Hence, ignoring the comorbid condition in cost benefit analysis leads to an underestimation of the benefit of an intervention regarding the index condition under the plausible assumption of nonnegative U_{12}.

The above conclusion is the opposite of that of HARRIS and NEASE (1997). This follows because H-N’s model is one-dimensional, containing only health effects, while our model is two-dimensional and considers interactions between health and wealth

3. Random comorbidity

Suppose now that disease 2 is also random. We wonder how changes in either its likelihood $\left(p_2\right)$ or its severity $\left(M_2\right)$ affect each of the two W.T.P. concepts. Hence we have to examine four partial derivatives obtained by differentiating (1.4) and (1.5) each with respect to p_2 and M_2. For instance we have :

$$\frac{\partial}{\partial p_2}\left(\frac{dW}{dp_1}\right)=\frac{N\left[-\left(U\left(H_{12}\right)-U\left(H_1\right)\right)+\left(U\left(H_2\right)-U\left(H_0\right)\right)\right]}{}$$

$$\frac{-M\left[p_1\left(U_1\left(H_{12}\right)-U_1\left(H_1\right)\right)+(1-p_1)\left(U_1\left(H_2\right)-U_1\left(H_0\right)\right)\right]}{N^2} \tag{3.1}$$

where for notational convenience U(W,H) was replaced by U(H) since W is the same in each expression.

Consider first the term $-\left(U\left(H_{12}\right)-U\left(H_1\right)\right)+\left(U\left(H_2\right)-U\left(H_0\right)\right)=R$. Because $H_1-H_{12}=H_0-H_2$ and $H_0>H_1$ it follows by risk aversion with respect to health that R is strictly positive. Figure 1 illustrates this claim. Concavity of U in H implies that $ba\left(=U\left(H_1\right)-U\left(H_{12}\right)\right)$ exceeds $dc\left(=U\left(H_0\right)-U\left(H_2\right)\right)$.

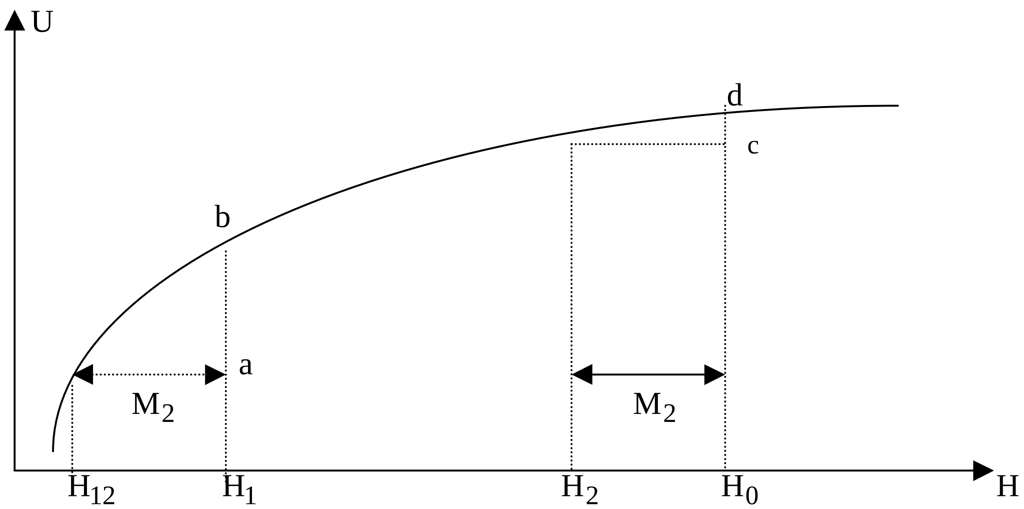

Figure 1 : **Illustration that R is strictly positive**

Let us now turn to the sign of the term $\left[p_1\left(U_1(H_{12})-U_1(H_1)\right)+(1-p_1)\left(U_1(H_2)-U_1(H_0)\right)\right]=S$. Because $H_1>H_{12}, H_0>H_2$, and since we have assumed that $U_{12}>0$, it follows that S is strictly negative and thus the term $-M*S$ is strictly positive. Hence, (3.1) consists of two strictly positive terms and thus the relationship between changes in p_2 and changes in $\frac{dW}{dp_1}$ is positive. If the probability of the comorbid increases, the patient is willing to pay more to reduce the probability of getting disease 1. Note that this conclusion also holds true if either $U_{22}=0$ (risk neutrality) and $U_{12}>0$ or $U_{22}<0$ and $U_{12}=0$ (no interdependence between the utility of health and the utility of wealth). In the first case, R = 0 and hence N*R = 0, but S < 0 and thus –M*S > 0. Consequently, the sign of $\frac{\partial}{\partial p_2}\left(\frac{dW}{dp_1}\right)$ remains strictly positive. In the second case, S = 0 and thus –M*S = 0, but N*R remains strictly positive by risk aversion and thus the sign of $\frac{\partial}{\partial p_2}\left(\frac{dW}{dp_1}\right)$ remains strictly positive.

Similar arguments as those applied to $\frac{\partial}{\partial p_2}\left(\frac{dW}{dp_1}\right)$ show that $\frac{\partial}{\partial M_2}\left(\frac{dW}{dp_1}\right)$, $\frac{\partial}{\partial p_2}\left(\frac{dW}{dM_1}\right)$ and $\frac{\partial}{\partial M_2}\left(\frac{dW}{dM_1}\right)$ are also strictly positive under $U_{22}<0$ and $U_{12}\geq 0$ or $U_{22}=0$ and $U_{12}>0$[5].

The above analysis shows that the risks tend to reinforce each other. When the comorbid conditions deteriorate the patient is willing to pay more to improve the index condition. Quite interestingly this result holds true even if $U_{12}=0$ that is when health and wealth are « utility independent ».

Finally observe that the results in Sections 2 and 3 are qualitatively equivalent. In fact, Section 2 can now be viewed as a special case of Section 3 with p_2 equal to unity.

4. A mean preserving change in risk for the comorbid condition

In the previous sections, we have considered changes in the comorbid conditions that would always increase its expected severity. Indeed when p_2 or M_2 increase, $p_2.M_2$ is also necessarily increasing. In fact changes in p_2 or in M_2 determine shifts in risk which are of a first order stochastic dominance nature (see fn 3 below for a definition).

We now turn to the impact of a joint change in p_2 and in M_2 such that expected severity $(p_2.M_2)$ remains constant. If p_2 falls while M_2 increases with $p_2 M_2$ constant it is said that the comorbid condition becomes riskier[6] while its mean is preserved.

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[5] The proof which is easy but tedious can be obtained from the authors.

[6] In a more recent terminology one might say that the comorbidity condition becomes « catastrophic ». See ZECKHAUSER (1995) for a definition.

We illustrate in details the impact of a mean preserving increase in risk (M.P.I.R.) for the comorbid condition on W.T.P. for a reduced probability of the index condition. A similar analysis with the same type of conclusions[7] can be reached as far as the W.T.P. for a reduced severity is concerned.

To determine the impact of a M.P.I.R. on W.T.P., we differentiate (1.4) with respect to p_2 and M_2 keeping in mind that $p_2 M_2$ is constant so that :

$$\frac{dM_2}{dp_2} = -\frac{M_2}{p_2} \tag{4.1}$$

We obtain

$$\frac{d}{dp_2}\left(\frac{dW}{dp_1}\right)\Bigg|_{p_2M_2=C^t} = \frac{N \cdot \dfrac{\partial M}{\partial p_2}\Big|_{p_2M_2=C^t} - M \cdot \dfrac{\partial N}{\partial p_2}\Big|_{p_2M_2=C^t}}{N^2} \tag{4.2}$$

where C^t denotes « constant ».

Besides

$$\begin{aligned}\frac{\partial M}{\partial p_2}\Big|_{p_2M_2=C^t} &= -\left[U(W,H_{12}) - U(W,H_1) + p_2U_2(W,H_{12}) \cdot \frac{M_2}{p_2}\right] \\ &\quad + \left[U(W,H_2) - U(W,H_0) + p_2U_2(W,H_2) \cdot \frac{M_2}{p_2}\right]\end{aligned} \tag{4.3}$$

and

$$\begin{aligned}\frac{\partial N}{\partial p_2}\Big|_{p_2M_2=C^t} &= p_1\left[U_1(W,H_{12}) - U_1(W,H_1) + p_2U_{12}(W,H_{12}) \cdot \frac{M_2}{p_2}\right] \\ &\quad + (1-p_1)\left[U_1(W,H_2) - U_1(W,H_0) + p_2U_{12}(W,H_2) \cdot \frac{M_2}{p_2}\right]\end{aligned} \tag{4.4}$$

Given our assumption of risk aversion, i.e., $U_{22} < 0$, we show in Appendix 2 that the sign of $\frac{\partial M}{\partial p_2}\Big|_{p_2M_2=C^t}$ is negatively related to that of U_{222}. We also show that given $U_{12} > 0$, the

[7] Available from the authors upon request.

sign of $\left.\frac{\partial N}{\partial p_2}\right|_{p_2 M_2 = C^t}$ is negatively related to the sign of U_{122}. Hence, the impact of a mean preserving increase in the comorbidity risk on the W.T.P. for reductions in p_1 depends on the signs of U_{222} and U_{122}. If $U_{222} > 0$ and $U_{122} < 0$ then a mean preserving increase in the comorbidity risk increases the W.T.P. for a reduction in the probability of the index condition[8].

We observe that the impact of a mean preserving increase in risk on the W.T.P. depends not only on conditions regarding the second order derivatives of U, but also on conditions regarding the third order derivatives. The third order derivatives may appear unintuitive. However, they can be given an interpretation in terms of actual behavior. Let us start with U_{222}. $U_{222} > 0$ implies that the people are *prudent* with respect to health. The notion of prudence was first proposed by KIMBALL (1990) in a model of saving under income risk where he built upon partial results obtained in the same context by LELAND (1968) and SANDMO (1970). In that context, prudence means that people will increase their saving today to forearm themselves against future income risk. KIMBALL has shown taht if U_{222} is strictly positive then people will save more when future income risk increases. In the context of our model, $U_{222} > 0$ means that people would like to increase their expected health stock (e.g. by spending more on treatment) if it were to become more random (see Appendix 3).

U_{122} is related to the sensitivity of a patient's attitude regarding health risks to changes in wealth. Indeed the latter is equal to :

$$\frac{\partial\left(-\frac{U_{22}}{U_2}\right)}{\partial W} = -\frac{U_{122}U_2 - U_{22}U_{12}}{U_2^2} \tag{4.5}$$

$U_{122} < 0$ is a necessary condition for the patient to become less averse to health risks when his wealth increases.

5. <u>Conclusion</u>

We have shown that a patient's willingness to pay for improvements in his index condition increases with the severity of his comorbid conditions. In most of the cases we examined this positive relationship depends on risk aversion regarding health risks and on positive interdependence between the utility of wealth and the utility of health, assumptions that are plausible and that have been supported in empirical studies. In the case of a mean preserving increase in risk, additional assumptions regarding the third derivatives of the utility function for health and wealth must be invoked. These assumptions seem reasonable, but have not been tested empirically. Testing these assumptions is a topic for future research.

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[8] To be complete, this also holds if either U_{222} or U_{122} is zero and even if either U_{22} or U_{12} is zero.

Our analysis emphasizes the importance of incorporating information on comorbidities in the elicitation of willingness to pay measures. Without this information, willingness to pay measures are likely to be biased downwards. Our analysis also has important implications for health policy. For instance, cost-benefit analysis is often said to discriminate against the elderly who are supposed to derive less benefit from prolonged longevity. This argument should be qualified if – as is plausible – age positively covaries with the severity of the comorbidities.

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