Utilizing HealthCoins as an Incentivization Method to Finance Gene Therapies in a Public and Private Payer Environment

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ABSTRACT

A current challenge of financing gene therapies in a multi-payer environment is the free-rider problem where one insurer (payer) could wind up covering the full one-time cost of a cure for a patient who then moves to a second insurer who then captures the value of the healthier patient. As a result of this problem, insurers are unwilling to pay for the cure. A recent paper (Basu 2016) proposed the concept of HealthCoin as a tool to transfer value added in a multi-payer environment that incentivizes private payers to pay for expensive, long-term cures. This paper is an extension of the HealthCoin concept and discusses whether it can be applied to financing gene therapies. We conducted discounted cash flow analyses on two selected therapies, Luxturna from Spark Therapeutics (Inherited Retinal Disease) and AMT-061 from UniQure (hemophilia B). A successful implementation of HealthCoins incentivizes private payers to treat patients upon diagnosis and results in reduced costs for both private payers and the public payer (i.e. Medicare). Nevertheless, some scope conditions and assumptions must be satisfied to make the HealthCoin implementation feasible.

Introduction

Gene therapy, a promising and revolutionary field of therapeutics, was first discussed in the 1960s and eventually made headlines in 1971 when Merril, *et al.* published, "Bacterial Virus Gene Expression in Human Cells". The paper describes an experiment in which DNA can be injected into human cells to restore missing enzyme activity. Inspired by these results, Friedmann and Roblin published a formal proposal in *Science* to use gene therapy as a means to treat human genetic diseases in 1972.[1] Since then, scientists have made significant progress in the field of gene therapy.

In 2012, the European Medicines Agency (EMA) approved Glybera for the treatment of pancreas disease caused by the missing gene that encodes for lipoprotein lipase. While Glybera proved to work biologically, the drug failed commercially because it was far too expensive; at a cost of $1 million dollars per treatment, patients were denied coverage by insurers. UniQure, the inventor of Glybera, eventually discontinued the drug, and as of 2018, Glybera is no longer listed in the company's pipeline.

How is it possible that society has the means to produce an effective treatment, yet at the same time be unable to absorb the economics to ultimately benefit the public? Although healthcare insurance was specifically designed to reduce financial burden for those in need of expensive medical services, many insurers, especially private ones, will only provide access so long as cost does not exceed a certain threshold. While healthcare policy in the United States has evolved drastically from where it was in the early 1990s (and from when Glybera was first introduced) to today, there still exists many challenges with regards to pricing and

access. As a collective medium to de-risk exorbitant expenses, private insurance companies face the monumental task of providing healthcare services to those in need while at the same time providing positive returns to investors. Under ideal conditions, mathematics and statistics suggests it may be possible to de-risk and still collectively benefit all stakeholders. However, reality is far from that, and there exists significant challenges beyond the numbers that encumber the medical system.

One challenge to providing gene therapy cures is access to capital. For example, if a certain disease affects millions of Americans but price per treatment is one million dollars, there would not exist enough net premiums written for the insurer to handle all claims made in a single year, thereby creating significant financial burden.

While access to capital is certainly an important challenge that needs to be tackled, it alone is not enough to solve the problem of financing of cures in the US. This is because a second major challenge exists: insurance carrier switching, leading to the problem of "free-riding". Based on recent insurance sector surveys, the average U.S. consumer switches health plans every two or three years due to job changes or his or her employer switching insurance plans.[2] Consequently, no insurer wants to pay for the expensive lifelong cure only for its consumer to switch insurers and let the next insurer "free ride" on that investment. This "free-rider" problem occurs because a cure is valued by all private and public payers, yet no one payer can exclude the others from obtaining some value associated with a cure. This fear of "free-riding" has created a dynamic in which there is an underinvestment in one-time, but expensive cures.

In our analysis, we focus on addressing this second challenge. We examine how to potentially finance two different gene therapies, AMT-061, UniQure's potential cure for hemophilia B (also known as Factor IX deficiency), and Luxturna, Spark Therapeutics' recently approved cure for Inherited Retinal Disease (IRD), through the use of HealthCoins to balance the incentive schemes of investing in lifelong cures between private and public insurers.

Literature Review

A new financing mechanism, HealthCoins, incentivizes private insurance companies to invest in breakthrough therapies or cures in the US

A recent paper written by Dr. Anirban Basu of the University of Washington (2016) discusses a way to potentially resolve this "free-rider" problem using a new currency, HealthCoin, backed by the US government.[3] The idea is that the first healthcare provider invests in the cure for the beneficiary and the beneficiary is treated, producing a certain number of HealthCoins that are valued by the cost and the expected lifetime value of the cure. If the beneficiary switches healthcare providers, then the next provider is required to buy the beneficiary's HealthCoins from the previous provider. When the beneficiary enters Medicare, Medicare is required to buy the remaining health coins from the last provider. The paper explains how HealthCoins would be valued from the perspective of the private payer and Medicare in the context of a hypothetical cure for type 2 diabetes. Specifically, the paper

values a HealthCoin that Medicare would be willing to pay a private payer for a beneficiary who is transitioning to Medicare at age 65, if the private payer had invested in a cure for diabetes before then.

Theoretical setup

1) The cure is a lifelong cure.
2) The cure applies to all ages of patients at a fixed price and is 100% effective at all ages.
3) Both the private payer and Medicare pay the same price P_{Cure} .
4) All patients are insured starting from birth, and switch from private insurers to Medicare at age 65.
5) Medicare would buy the present value of the HealthCoins from the private insurers as patients become transfer over to Medicare.
6) Private payer's decision follows maximizing the net monetary benefits (NMBs) since a private payer can restrict coverage for a drug on the basis of its costs.
7) Medicare must provide coverage to all health care interventions that are effective and necessary. It is prohibited by Congress to look at costs in making coverage decisions, and therefore, cannot reject an expensive therapy if it is deemed effective.

Medicare Perspective

Medicare would be willing to pay the private payer a HealthCoin $\leq P_{Cure}$ for a cured diabetes patient at age 65. Otherwise, Medicare would invest in the cure itself.

Private Payer Perspective

Given that the expected lifetime value of a cure for diabetes for all nonelderly adults is $EINMB_{NE,\ Private}$, the private payer would have the incentive to buy the cure for its beneficiary if $P_{Cure} < EINMB_{NE,\ Private}$. If $P_{Cure} > EINMB_{NE,\ Private}$, then the private payer would not have an incentive to purchase cures unless it receives HealthCoins from Medicare when the patient turns 65 years old. As a result, the private payer would be willing to pay if it can receive HealthCoin $\geq (P_{Cure} - EINMB_{NE,\ Private})/S$, where S is the fraction of patients receiving the cure who survive to the age of 65.

Valuation of HealthCoin for Diabetes Cure at Age 65 Years

For HealthCoins to benefit both Medicare and the Private Payor, it must be valued as such:

$$P_{Cure} \geq \text{HealthCoin} \geq (P_{Cure} - EINMB_{NE,\ Private})/S$$

Results of Analysis

The paper found that there are a range of HealthCoin values that would satisfy the above equation. The midrange value for a HealthCoin in one case is $211,154. Taking that HealthCoin value, the paper found the following:

Without HealthCoins, the private payer would not have the incentive to cure patients, and 507,000 of them survive to age 65, at which Medicare would cure them at a P_{Cure} of $229,183, resulting in a total cost of $116Bn. The returns on the now healthier and cured patients are $81Bn, resulting in a net loss of -$35Bn.

With HealthCoins, the net cost of treating all 1.34 million patients would be $122 billion (the cost of curing all the patients and adding back the return from the HealthCoin collected from each healthy patient that reaches 65 years). Additionally, the private payer receives $102,879 of benefits for each cured and now healthier patient. As a result, the private payer would have a net positive of $16Bn ($138Bn - 122Bn). On the Medicare side, it would incur $185Bn in costs of the HealthCoins paid to the private payer for each cured patient that reaches age 65. Medicare would incur returns of $202Bn, which comprises of the $81Bn generated among 507,000 patients who would have been cured at age 65 years even without the HealthCoin and the additional 369,000 patients who reach age 65 years with their diabetes cured and live their expected life expectancies. As a result, Medicare would have a net positive of $17Bn ($202Bn - $185Bn).

Implications

A HealthCoin currency could be valued in such a way that would incentivize a private payer to invest in the Type 2 Diabetes cure for its beneficiaries, making itself, Medicare, the drug manufacturer and patients better off. More generally, the financial analysis of the Basu paper illustrates that issuing a HealthCoin could increase gains for all actors involved, especially for cures that are in demand in nonelderly years (<65) and will produce health benefits throughout the life of the patient, especially after age 65.

Relevance to Our Project

The Basu paper concludes with a call to further discussions around the applicability of HealthCoin for breakthrough therapies on the horizon, such as gene therapies for blindness and hemophilia B. Our project aims to use similar financial analysis methods to assess the applicability of a HealthCoin for Spark Therapeutic's Luxturna, a gene therapy for Biallelic RPE65-Mediated Inherited Retinal Disease, and for Uniqure's AMT-061, a gene therapy in development for hemophilia B.

Medicare

As of 2019, Medicare is a government sponsored medical program for Americans who are age 65 and older. Once an individual reaches this age, he or she automatically qualifies for Medicare, but the individual has the option to opt out and continue with private medical insurance. Additionally, Medicare must provide coverage to all health care interventions that are effective and necessary. It is prohibited by Congress to look at costs in making coverage decisions, and therefore, cannot reject an expensive therapy if it is deemed effective (Basu 2016).

With respect to Basu's approach, our analysis also imagines a scenario in which all individuals who reach age 65 are mandatorily transferred to Medicare coverage. In such manner, we are able to separate out costs between private and public insurers to easily dissect incentive schemes in our discounted cash flows analysis, but more importantly, introduce a system in which the responsibility of curing, rather than treating patients, is placed on both private and public payers. This mitigates the issue of insurance switching and "free-riding" because private payers now have incentives to cure all patients so that they can receive financial compensation via HealthCoins. The earlier treatment is initiated, the greater the financial benefit to private payers and larger amount of cost savings on the total healthcare system. By creating a multi-payer system in which the full value of a cure can be dispersed and introducing HealthCoins, it may be possible to rebalance incentives.

Inherited Retinal Diseases

Inherited retinal diseases (IRDs) are a group of rare eye disorders caused by an inherited gene mutation that can lead to the loss of functional vision and often blindness.[4,5] IRDs are categorized into several types: Leber congenital amaurosis (LCA), Retinitis Pigmentosa (RP), Cone-Rod Dystrophy (CRD), Juvenile Macular Degeneration (JMD), and Choroideremia (CHM).[6]

LCA is regarded as the severest of IRDs. Patients are usually diagnosed with LCA in infancy and eventually leads to childhood blindness. They have signs of involuntary eye movement, night blindness, and extreme farsightedness. It is known to be caused by mutation in at least six genes. *RPE65*, one of the mutated genes, expresses an enzyme called retinoid isomerohydrolase in the retinal pigment epithelium (RPE). The enzyme is critical in the visual cycle by producing chromophore. The failure of chromophore production due to a genetic mutation leads to a severe loss of vision.[7]

RP is the most common retinal dystrophy affecting 1 in 3,000 individuals and is caused by deterioration of light-sensing cells of the retina (rod and cone photoreceptors). General symptoms include night blindness and loss in peripheral vision, leading to total blindness. Research on RP has shown that it may be caused by mutations in at least 50 genes, one of which is the *RPE65* gene, and can be inherited in an autosomal dominant, autosomal recessive, or X-linked manner.[8]

As of 2013, one report shows that there are approximately 4,500,000 patients who have inherited forms of retinal disease worldwide and 200,000 patients in the United States. RP patients consist of 40% of US patients (~80,000 people) whereas LCA patients consist of 5%, (~10,000 people).[9]

Standard of Care (SOC) for IRD

Direct medical costs for SOC treatments include costs for ophthalmic related treatments such as angiography or tomography, and medical costs related to depression or trauma. Focusing on direct medical costs, we estimated the current standard of care costs to

be $2,511 per year based on a research paper that found the total cost for SOC treatment to be $213,400 (Table 1).[14]

Table 1. QALYs and costs over the remaining lifetime of an individual treated with Luxturna and Stand of Care (SoC). Black box is a section that we are interested in for financial analysis.[14]

Table 3 – QALYs and costs over the remaining lifetime of an individual treated with VN and SoC.

Treatment	SoC	VN	Incremental
QALYs	16.0	17.3	1.3
Direct medical costs			
Voretigene costs	$0	$854 876	$854 876
AE costs	$0	$222	$222
Direct ophthalmic medical costs	$138 833	$144 793	$5 960
Direct medical costs, depression	$6 834	$7 171	$336
Direct medical costs, trauma	$67 731	$31 957	−$35 774
Total	$213 399	$1 039,019	$825 621

AAV based gene therapy

A treatment that is currently in the research stage is gene replacement therapy by using viral vectors such as AAV vectors (Figure 1).[10] AAV is a common gene transfer vector used to deliver a normal functional copy of the gene into target cells. AAV is composed of a shell of capsid proteins and a single copy of the AAV DNA located inside the shell. Depending on the type of target cells, desired capsid proteins can be chosen. Key advantages of AAV as a viral vector are: 1) it is not highly immunogenic, 2) it can target both dividing cells and non-dividing cells. However, it also has drawbacks such as a cloning capacity limited to short base pairs compared to other viral vectors.

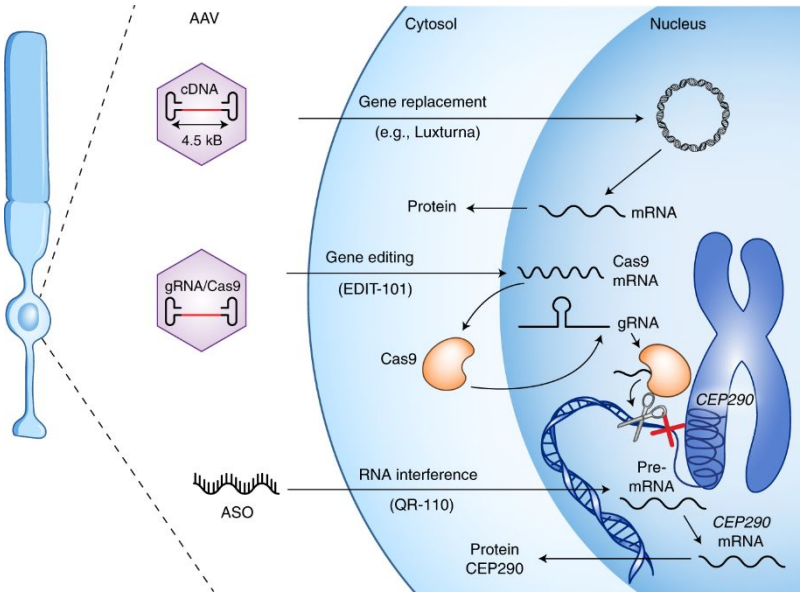

Figure 1. Nucleic-acid-based therapies for inherited retinal diseases[10]

Spark Therapeutics

As gene therapy has become a revolutionary approach to mitigating disease progression and possibly improving vision in patients with IRDs, a number of companies have been developing their own gene delivery methods in the past decades.

Table 2. List of sponsors working on gene therapy for inherited retinal diseases[11]

TABLE. GENE THERAPY CLINICAL TRIALS FOR INHERITED RETINA DISEASES*				
DISEASE	GENE	VECTOR	DELIVERY	SPONSOR(S)
Phase 3 Complete, Approved by US FDA				
LCA and RP	*RPE65*	AAV	Subretinal	Spark Therapeutics
Current Clinical Trials				
Achromatopsia	*CNGA3*	AAV	Subretinal	AGTC, Tübingen Hospital
Achromatopsia	*CNGB3*	AAV	Subretinal	AGTC, MeiraGTx
Choroideremia	*CHM*	AAV	Subretinal	Spark Therapeutics, Nightstar Therapeutics, Tübingen Hospital
LCA	*CEP290*	N/A	Intravitreal	ProQR
LCA and RP	*RPE65*	AAV	Subretinal	MeiraGTx
RP	*MERTK*	AAV	Subretinal	King Khaled Eye Specialist Hospital
RP	*PDE6B*	AAV	Subretinal	Horama
RP (Optogenetic)	*ChR2*	AAV	Intravitreal	Allergan
RP (Optogenetic)	*ChrimsonR*	AAV	Intravitreal	GenSight Biologics
Stargardt disease	*ABCA4*	EIAV	Subretinal	Sanofi
Usher syndrome type 1	*MYO7A*	EIAV	Subretinal	Sanofi
X-linked RP	*RGPR*	AAV	Subretinal	AGTC, Nightstar Therapeutics, MeiraGTx
X-linked retinoschisis	*RS1*	AAV	Intravitreal	AGTC, NEI

* The most advanced completed, currently active, or soon-to-be-activated gene therapy treatment trials for retinal dystrophies registered in the online database clinicaltrials.gov.
Abbreviations: AAV, adeno-associated virus; AGTC, Applied Genetic Technologies Corporation; EIAV, equine infectious anemia virus; LCA, Leber congenital amaurosis; N/A, not applicable; NEI, National Eye Institute; RP, retinitis pigmentosa

Table 2 shows the list of companies currently working on gene therapy clinical trials for inherited retinal diseases.[11] Spark Therapeutics is the only company that has been approved by the FDA. Luxturna (voretigene neparvovec-rzyl) is a gene therapy developed by Spark, targeting patients with viable retinal cells and confirmed biallelic *RPE65* mutation-associated retinal dystrophy. To be eligible for Luxturna, patients must be diagnosed with LCA or RP, and confirmed with genetic test to determine if there is a defect in both *RPE65* genes. Also, patients must have enough functional retina to restore vision after the treatment. Spark estimates that the number of people who fulfill all these criteria to be ~1,000-2,000 in the US.[12]

Price of Luxturna treatment

Spark announced the price of Luxturna to be $0.425m per eye or $0.85m per patient.[13] It also unveiled three novel payer programs to give eligible patients better access to the treatment. First, is an installment model which would allow for a series of payments over

time rather than all at once and up front. Second, is an outcomes-based rebate arrangement. In case the treatment does not work for patients and fails to meet specified standards, the company will share the risk with health insurers. The treatment is evaluated on two measures: short-term efficacy (30-90 days) and long-term durability (30 months) measures. Third, is a contracting model suggesting an option for direct-to-payer contract between patient and developers.[12]

Hemophilia B

Hemophilia B is a rare X-linked recessive severe bleeding disorder caused by a deficiency of coagulation factor IX. Since the disease is X-linked recessive, it occurs predominantly in males at a rate of 1 in 500 male births in the US. Approximately, 4,000 people in the US are diagnosed with Hemophilia B.[15]

Due to a lack of clotting factors, hemophilia B patients experience prolonged bleeding following an injury or surgery. The bleeding might occur after minor trauma or even spontaneously without any injury. The extent of symptoms can be categorized as severe, moderate, and mild as shown from Table 3.[16]

Table 3.Types of hemophilia[16,17]

Severity	Bleeding Episodes	Percent of Hemophilia B patients
Severe (<1% of normal level)	Spontaneous bleeding into joints or muscles, predominantly in the absence of identifiable hemostatic challenge	27%
Moderate (1-5% of normal level)	Occasional spontaneous bleeding; prolonged bleeding with minor trauma or surgery	36%
Mild (5-40% of normal level)	Severe bleeding with major trauma or surgery. Spontaneous bleeding is rare	37%

Standard of Care for hemophilia B

Clotting factor replacement therapy

The most common treatment for hemophilia patients is clotting factor replacement therapy. Concentrates of clotting factor IX (FIX), extracted from donated human blood, are slowly injected into a patient's vein. Recombinant clotting factors may also be injected. The replacement therapy is categorized as demand therapy and preventive (prophylactic) therapy depending on the requirement of periodic injection.[18] This current therapy, however, has several shortcomings. For instance, patients may produce antibodies which attack the introduced clotting factor. Therefore, therapeutic levels of clotting factor usually cannot be achieved even with very large doses. This occurs in 5-8% of hemophilia B patients, who have large deletions or major abnormalities of the FIX gene, making this therapy inefficacious.[19] Furthermore, replacement therapy is required regularly, leading to inconvenience for the patient. The recommended dosage of these products is dependent on the weight of patients and severity of symptoms. For instance, Alprolix, recombinant factor IX product, is

recommended to start 50 IU/kg once weekly and adjust dosage based on individual response.[20] Lastly, in patients who have inhibitors, antibodies that recognize clotting factors as antigens provoking an allergic reaction after injecting FIX, there is a need for higher doses of drug, resulting in costs rising to $1m.[21]

UniQure

UniQure is one of the companies leading the commercialization of gene therapy for hemophilia B. One of its lead candidates (AMT-061) is a gene therapy for hemophilia B. AMT-061 utilizes an AAV5 vector incorporating FIX-Padua variant (FIX-Padua). The process of AMT-061 for gene therapy includes intravenous infusion through the peripheral vein in a single treatment session without immunosuppressant therapy. The commercialization of AMT-061 has been accelerated in 2017 as the U.S. Food and Drug Administration (FDA) granted breakthrough therapy designation (BTD) to AMT-061 based on results from AMT-060, its sister gene therapy.[22]

Estimated price of gene therapy for hemophilia B

Currently, there is no FDA approved gene therapy for hemophilia B. However, its cost can be estimated based on direct medical costs and FDA-approved gene therapy costs for retinal diseases (Luxturna) which sets a precedent.[23] The cost of Luxturna was considered according to Harvard Pilgrim framework, which defines a 30-month cutoff for the efficacy of Luxturna, and was applied to the gene therapy for hemophilia B as well. Direct medical costs were estimated based on annual costs of Alprolix, a medicine for coagulation replacement therapy. Assuming 3-4 times of medicine consumption per week, annual costs for adult patients range from $0.58m to $0.80m per patient and midpoint cost is $0.65m as shown in Figure 2.[23] If the midpoint cost ($0.65m) and durability requirement (30 months) are used, a price tag for hemophilia B gene therapy can be estimated as $1.5m. It was previously mentioned that the cost of factor replacement therapy might increase up to $1m in the case where patients have inhibitors to clotting factors.[21] Compared with this, price of gene therapy as a one-time cure can be justified as feasible to insurers. This estimated price was used in our financial analysis to discuss the efficacy of HealthCoins in the case of hemophilia B.

Assumption 1: Hemophilia B

Baseline FIX (IU/dL)		1	Baseline FIX (IU/dL)		1
Body weight (kg)		75	Body weight (kg)		95
Treatment frequency (/week)		1	Treatment frequency (/week)		1
Treatment	Alprolix (hemophilia B)		Treatment	Alprolix (hemophilia B)	
Target FIX (IU/dL)		50	Target FIX (IU/dL)		50
Units needed		49	Units needed		49
Alprolix units for treatment (/week)		3,675	Alprolix units for treatment (/week)		4,655
Yearly treatment (weeks)		52	Yearly treatment (weeks)		52
Alprolix units for treatment (/year)		191,100	Alprolix units for treatment (/year)		242,060
Alprolix price (WAC)	$	3.03	Alprolix price (WAC)	$	3.03
Yearly treatment cost	$	579,033	Yearly treatment cost	$	733,442

Figure 2. Annual cost of factor replacement range for hemophilia B between $0.58m and $0.8m[23]

Financial Analysis

Summary

We conducted a discounted cash flow analysis for Spark Therapeutic's Luxturna and UniQure's AMT-061. The result for the Luxturna analysis showed that a lump-sum payment less than $1.09 billion from Medicare to private payers immediately after the development of a gene therapy can incentivize the private payers to treat all patients at hand (Table 7). With the price of a HealthCoin between $0.74m to $0.85m, the private payers will continue to have the incentive to treat patients upon diagnosis. As for AMT-061, no lump-sum payment or HealthCoin is needed because the private payers already have enough motivation to treat all patients; this is because of the relatively low price for the gene therapy compared to the cumulative medical cost for alternative treatments.

Experimental Setup

Several assumptions were made in order to reach the aforementioned result. We assume that all patients are under healthcare coverage by a private payer since birth, and that all patients survive to the age of 65 will be transferred to Medicare. An alternative treatment exists which does not significantly alter the disease progression, and a gene therapy provides a one-time permanent cure for the disease. There is a fixed annual medical cost for the alternative treatment, and a fixed price associated with the one-time gene therapy. Medicare is required to cure the patients with gene therapy when they are transferred from a private payer. Based on the data[17], we further approximate that most cases of inherited retinal disease and hemophilia B are diagnosed within one year of birth.

Data Acquisition

We first separate the patients into four subpopulations, at age 0 when they are diagnosed (#newcase), between age of 0 to 65 when the insurance is covered by a private payer (#young), at age 65 when they are transferred to Medicare (#transferred), and at age above 65 when they are covered by Medicare (#old). Since most cases of inherited retinal disease are not life threatening, we used the age distribution of US population from 2017 US Census data to approximate the age distribution of inherited retinal disease patients. The total number of US patients that are targeted by Luxturna is found in Spark Therapeutics' 10k report[12], and each subpopulation is then prorated from this total patient count. The calculation of hemophilia B subpopulation followed a similar process. We got the total number of hemophilia B patients in the US from hemophilia Federation of America, and inferred the relative percentage of each subpopulation using a survival curve as shown from Table 4 and Table 5.[24]

The cost of alternative treatment and the price of gene therapy for both inherited retinal disease and hemophilia B can be found in published reports and public database.[23,25,26]. For inherited retinal disease, we estimated the current standard of care costs to be $2,511 per year[14], and the price of Luxturna is set to $0.85m for both eyes.[13] For hemophilia B, the current standard of care costs $0.65m per year, and the estimated price of a gene therapy is $1.5m (Table 5).[23]

Discounted Cash Flow Analysis

The current time of the cash flow analysis is set to the time when a new gene therapy is available on the market. We assume that there is enough of the gene therapy cure that all patients can be cured in one year as long as the payment is received. Therefore, the analysis can be separated into two parts, the "transition state" and the "steady state". The transition state is equivalent to year 0 in the analysis where a private payer can decide to either cure all the patients at hand or continue providing alternative treatments. At the same time, Medicare is required to cure all existing patients above the age of 65 under its coverage. In the following years (i.e. steady state), all new cases diagnosed are newborns and therefore are either cured immediately by a private payer or receive continuous alternative treatment before being cured by Medicare at 65.

The pro-forma cash flows are shown in Table 6. We compare the two situations where private payers either cure the patients with gene therapy under coverage or only provide alternative treatments. The cash flows under steady state can be treated as a perpetuity, and the discount rate is set to 3% to account for inflation. The private payer needs to spend an extra $1.48Bn to provide Luxturna to patients, whereas it will save $108Bn by providing gene therapies for hemophilia B.

HealthCoin Implementation

Because of the extra cost associated with providing Luxturna, the private payer will need an incentive to do so. The HealthCoin is designed to transfer the incremental value captured by Medicare to private payers for this purpose. The maximum amount of this payment is the cost saved by Medicare, and the minimum is the extra cost paid by the private

payer. We then get the range of possible HealthCoin prices by dividing this payment by the number of patients transferred to Medicare each year. This is essentially the per capita payment from Medicare to private payers.

The situation during the transition phase required special attention because most patients under private payers have received the alternative treatment since birth prior to the development of the gene therapy. Therefore, the incentive required from the private payer is different and should be separate from the HealthCoin mechanism discussed above. A lump sum payment at year 0 is a straightforward way to transfer the value.

The HealthCoin concept can potentially solve the lack of capital problem in private payers in the long term once the patients are transferred to Medicare and the payments are received; however, this would still incur a large expense to the Medicare system and it is worth noting that this paper does not provide a solution to the heavy financial burden caused by gene therapies on the overall healthcare system. There are several mechanisms suggested for the payment during the transition stage. A lump sum payment is simple but may be beyond affordability. On the other hand, spreading out the payment over a longer timescale is a way to avoid such burden and may be more feasible, and a point of future study.

Table 4. Age Distribution of IRD and hemophilia B

Age Distribution	**IRD**	**Hemophilia B**
0	1.21%	1.43%
65	1.10%	0.95%
0-65	85.48%	87.33%
>65	15.61%	12.86%

Table 5. Summary of Patient Subpopulation and Medical Cost

		IRD	**Hemophilia B**
Patient Population	**Notation**	**Patient Number**	
Total patient	-	1500	4000
0	#newcase	18	57
65	#transferred	16	38
0-65	young	1282	3493
>65	old	234	514
P_cure		850000	1500000
c		2511	650000

Notes:

#newcase	is the number of new diagnosis per year
#transferred	is the # patients who survive until 65
P_cure	is the price of the gene therapy cure
c	is the yearly cost of standard of care treatment per patient

Table 6. Pro-forma cash flows

Year	0	1	2	3	**NPV**
Private sector doesn't cure the patients; public sector cures at age 65					
Private payer	young*c	young*c	young*c	young*c	young*c/r
Public payer	old*P_cure	#transferred *P_cure	# transferred *P_cure	# transferred *P_cure	old*P_cure + TV1
Private sector cures the patients at diagnosis					
Private payer	young*P_cure	#newcase*P_cure	#newcase*P_cure	#newcase*P_cure	young*P_cure + TV2
Public payer	old*P_cure	0	0	0	old*P_cure

Notes:
Discount rate (r) = 3%
TV1 = #transferred*P_cure / r / (1+r)
TV2 = #newcase*P_cure/r/(1+r)

Table 7. HealthCoin Evaluation

Luxturna	NPV (Total price diff.)	Payment in Year 0	Steady state Payment per year
Private sector doesn't cure the patients; public sector cures at age 65			
Private payer	$107M	$3.22M	$3.22M
Public payer	$651M	$199M	$14.0M
Private sector cures the patients at diagnosis			
Private payer	$1590M	$1090M	$15.4M
Public payer	$199M	$199M	$0

	Lumpsum payment	Total	Price per HC
max price	$1480M	$1090M	$12.2M	$743K
min price	$452M	$0	$14.0M	$850K
Median	$967M	$543M	$13.1M	$796K

Hemophilia B	NPV (Total price diff.)	Payment in Year 0	Steady state Payment per year
Private sector doesn't cure the patients; public sector cures at age 65			
Private payer	$75.7B	$2.27B	$2.27B
Public payer	$2.62B	$0.77B	$57.1M
Private sector cures the patients at diagnosis			
Private payer	$8.01B	$5.24B	$85.7M
Public payer	$0.77B	$0.77B	$0

	Lumpsum payment	Total	Price per HC
max price	NA	$2.97B	NA	NA
min price	NA	$0	NA	NA
Median	NA	$1.48B	NA	NA

Conclusion and Discussion

HealthCoin represents a conceptually viable strategy to restructure incentive schemes such that private insurers become more willing to invest in expensive, lifelong curative therapies. By compensating private insurers so that they are able to bear higher upfront costs, total cost burden on the healthcare system is reduced by billions of dollars, bringing about positive social welfare from a financial perspective. From a quality of life perspective, such curative treatments will also bring about significant improvements to patients who will no longer have to worry about their health conditions.

Upon reflection in our analysis, HealthCoin is only a feasible solution for certain indications. In disease areas such as hemophilia B, the use of HealthCoins is unnecessary because the potential value to cure the disease more than already provides the correct financial incentives and motives to do so. Hence, private medical insurers are already willing to bear higher upfront costs to cure patients without need for support from public insurers and HealthCoin implementation. Where HealthCoin is an optimal strategy, is for financing cures in chronic diseases that already have cost-effective therapies but which only address disease symptoms (e.g. type 2 diabetes), or orphan indications that traditionally have had little to no treatments available (e.g. IRD). In these scenarios, because the existing cost burden per patient is relatively low for insurers, there exists a financial incentive for insurers to treat the symptoms with existing low-cost standard of care rather than with higher cost, but curative treatments that address the underlying disease. In these scenarios, HealthCoin is an effective solution to restructure incentives because it assists private payers by pooling capital from public payers. To effect, these cases will reduce overall cost burden in the healthcare ecosystem, and significantly improve patient quality of life.

While in theory HealthCoin represents a potential solution to imbalanced incentive schemes, successful implementation will heavily rely on policy reform from lawmakers. HealthCoin merely represents a solution, and execution in our complex healthcare payer environment is another significant hurdle. Without continued innovation from drug developers, reforms by policymakers and insurers, as well as buy-in from the general public, HealthCoin will only exist as an idea instead of a material solution.

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