Prediction of individual probabilities of livebirth and multiple birth events following in vitro fertilization (IVF): a new outcomes counselling tool for IVF providers and patients using HFEA metrics

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Prediction of individual probabilities of livebirth and multiple birth events following *in vitro* fertilization (IVF): a new outcomes counselling tool for IVF providers and patients using HFEA metrics

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Abstract

In vitro fertilization (IVF) has become a standard treatment for subfertility after it was demonstrated to be of value to humans in 1978. However, the introduction of IVF into mainstream clinical practice has been accompanied by concerns regarding the number of multiple gestations that it can produce, as multiple births present significant medical consequences to mothers and offspring. When considering IVF as a treatment modality, a balance must be set between the chance of having a live birth and the risk of having a multiple birth. As IVF is often a costly decision for patients—financially, medically, and emotionally—there is benefit from estimating a patient's specific chance that IVF could result in a birth as fertility treatment options are contemplated. Historically, a patient's "chance of success" with IVF has been approximated from institution-based statistics, rather than on the basis of any particular clinical parameter (except age). Furthermore, the likelihood of IVF resulting in a twin or triplet outcome must be acknowledged for each patient, given the known increased complications of multiple gestation and consequent increased risk of poor birth outcomes. In this research, we describe a multivariate risk assessment model that incorporates metrics adapted from a national 7.5-year sampling of the Human Fertilisation & Embryology Authority (HFEA) dataset (1991–1998) to predict reproductive outcome (including estimation of multiple birth) after IVF. To our knowledge, http://www.formyodds.com is the first Software-as-a-Service (SaaS) application to predict IVF outcome. The approach also includes a confirmation functionality, where clinicians can agree or disagree with the computer-generated outcome predictions. It is anticipated that the emergence of predictive tools will augment the reproductive endocrinology consultation, improve the medical informed consent process by tailoring the outcome assessment to each patient, and reduce the potential for adverse outcomes with IVF.

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Introduction

The decision to embark on the IVF journey is often accompanied by substantial financial and emotional stress. IVF patients therefore need a good understanding of their own chance that IVF might result in a birth before they finalize any treatment decision [1], although current efforts to provide this information early in the evaluation are typically based on cumulative clinic-specific data from IVF patients of similar age who previously attempted IVF at that institution. However, especially for older women, the outcome of the first IVF cycle is not predictive of subsequent IVF success [2], irrespective of where the treatment is offered later [3].

It is important for IVF providers to explain statistics on treatment outcomes and associated risks in an understandable way, so that patient expectations are not set unrealistically [4]. If this is not communicated accurately and effectively, patients may become discouraged and stop treatment. The need to develop a more sophisticated mechanism to estimate IVF outcome at the individual level can be reflected in drop-out rates among IVF patients. For example, during the study interval for our UK-based investigation, the average IVF patient completed only two cycles of treatment before either succeeding (in a minority of cases) or dropping out of IVF altogether [5]. There is no reason to believe that this circumstance is confined to IVF patients within this jurisdiction. At the same time, those who succeed with IVF may be unaware of the intrinsic risk of multiples even with "conservative" single embryo transfer [6], and unfamiliar with this risk increasing with each additional embryo transferred. Those who delay treatment likewise may be unaware of their declining chances of IVF success with each passing year. As a component of informed consent, patients and clinicians should welcome knowing the likelihood of having twins (or higher order multiple gestation) because of complications associated with such deliveries [7]. Moreover, the now widespread practice of transferring multiple embryos has been associated with an exponential increase in multiple pregnancies throughout the world [6]. Although embryo transfer policy changes in the UK resulted in a nearly 60% decline in three-embryo transfers, the number of two-embryo transfers increased by about the same percentage, and the number of single-embryo transfers remained stable between 1992 and 2007 [8]. In USA between 2003 and 2009, although the percentage of IVF triplets declined by 2.3% to 4.8% across all age groups, the percentage of twins has remained relatively constant at 14.8% to 33.5% [9].

Unfortunately, iatrogenic multiple gestation is associated with increased perinatal and maternal morbidity and mortality rates, all of which present considerable medical, social and health-related economic burdens on families and healthcare systems [10–12]. The financial and emotional costs of IVF treatment can be quite high, and, for some couples, prohibitive. Given the elective nature of assisted fertility treatments, IVF clinics often compete in terms of their "per cycle" success rates. These combined circumstances enhance the pressure, as seen in the UK, USA and elsewhere, to increase the number of transferred embryos (per cycle). This practice has sometimes been followed by national mandates limiting such practices, but often with a significant delay.

Against this background, more structured attempts to estimate reproductive outcome after IVF have been developed [13]. Treatment-specific factors have been identified to provide an accurate assessment of whether a patient has low or high risk of a successful outcome following IVF, although the initial approach was acknowledged to require further external validation. Our investigation extends this area of research by using an even larger population sample, gathered over a study interval of greater duration. We report an externally validated methodology for reliably predicting individual patient outcomes, including the chances of delivering a livebirth and the conditional probability (given a livebirth) of having a multiple birth at various times in the future. The application [http://www.formyodds.com] has subsequently been refined as an online predictive tool designed to help clinicians counsel patients who are contemplating IVF.

Methods

Data origin and tabulation

Data were derived from the Human Fertilisation and Embryology Authority (HFEA) assisted conception registry (UK), with permission granted by past HFEA chairpersons to the first author of this paper (CAJ). Since 1991, all IVF cycles initiated at licensed fertility treatment centres in the UK have been registered, and data on patient demographics, reproductive history, clinical characteristics of the IVF cycle, and birth outcomes were recorded by parliamentary mandate. The present analysis used anonymous registry data from July 1st 1991 to Dec 31st 1998. While the dataset used for this analysis is more than a decade old, the proportional odds of an IVF pregnancy resulting in multiple births, particularly following multiple embryo IVF transfer practices, has not changed significantly in the UK.

Table 1:

Odds of live birth (*n*= 13,222)

Variable	Odds Ratio	95% Confidence Interval
Age	[< 1.0]	(0.00, 999.74)
Age^2	[< 2.0] χ^{2*}	(0.79, 1.32)
Age^3	1.00 χ^{2*}	(1.00, 1.00)
Age cubic spline term	1.00	(1.00, 1.00)
Years infertile	[<1.0]*	(0.96, 0.99)
Number previous IVF cycles	[< 1.0]* χ^{2*}	(0.60, 0.73)
Previous IVF spline term	[< 2.0]* χ^{2*}	(1.30, 1.70)
Number previous live births	[<2.0]*	(1.05, 1.22)
History of endometriosis	[<1.0]*	(0.71, 0.85)
History of miscarriage	[<1.0]*	(0.52, 0.85)
History of ectopic pregnancy	[<1.0]*	(0.05, 0.53)
If 1 embryo is transferred	Reference	
If 2 embryos are transferred	[<4.0]*	(2.41, 3.74)
If 3 embryos are transferred	[<4.0]*	(2.89, 4.44)

*p< 0.01; ORs in brackets are generalised to a range in order to protect their proprietary novelty.

Table 2:

Odds of multiple birth, among cycles ending in live birth (*n*= 12,541)

Variable	Odds Ratio	95% Confidence Interval
Age	[< 1.0]* χ^{2*}	(0.96, 0.99)
Age linear spline term	[< 1.0]* χ^{2*}	(0.89, 0.96)
Years infertile	1.00 $\chi^{2\dagger}$	(0.97, 1.05)
Years infertile linear spline term	0.97 $\chi^{2\dagger}$	(0.92, 1.01)
Number previous IVF cycles	[<1.0]*	(0.89, 0.96)
History of endometriosis	[<1.0]*	(0.81, 0.95)
History of miscarriage	[<0.5]*	(0.28, 0.51)
History of ectopic pregnancy	[<1.0]	(0.02, 1.09)
If 1 embryo is transferred	Reference	
If 2 embryos are transferred	[<20]*	(6.73, 21.37)
If 3 embryos are transferred	[<20]*	(11.14, 35.20)

*p< 0.01; ; ORs in brackets are generalised to a range in order to protect their proprietary novelty.

†p< 0.05

Description of sample

In the period examined, 93,495 individual women and couples underwent a total of 174,418 cycles of IVF in 68 clinics. Cycles were excluded from analysis if treatment was abandoned before embryo transfer (*n*=3,274). Two unique samples, a model development and a model validation, were employed for each of two models. One model predicted the probability of having a live birth and the other estimated the conditional probability of having a multiple birth (given any live birth) over time. Note that "live birth", as defined by the HFEA, is in fact a "healthy baby" rate, as in any pregnancy from which an infant was born alive and remained viable for at least 28d. This HFEA definition is at variance with that of the World Health Organization (*i.e.* any born human being who demonstrates independent signs of life, including breathing, voluntary muscle movement, or heartbeat [14]).

Predicting a livebirth and multiple births from IVF

To model the predicted probability of achieving a livebirth after IVF, a random sample of 14,167 cycles was selected. This sub-set represented a low enough percentage of all cycles that there were no instances of patients re-entering treatment for subsequent IVF cycles (*e.g.*, one cycle = one patient). After developing this model, a random sample of 71,415 novel cycles was selected on which to perform validation analyses. To model the predicted probability of having a multiple birth given any livebirth (in the case of multiple births, given at least one livebirth surviving at least 28d), cycles were first excluded where they did not result in a live birth (*n*= 147,792). The remaining sample of IVF cycles was next evenly and randomly divided into a development sample and a validation sample (each class *n*=13,313). Two predictive models were thus created: one estimating the probability that an IVF cycle would result in a live birth, and another, modelled over time, estimating the conditional probability that an IVF cycle would result in a multiple birth, given any birth. For the first model, after exclusions, variables were stratified that were likely to be associated with the success of an IVF cycle and could be self-reported by the patient. These variables included: maternal age, number of previous pregnancies, number of previous miscarriages, number of previous livebirths (defined in this case as any previous baby born alive, stratified separately for natural vs. IVF conceptions),

Table 3:

Representative IVF cases and predicted reproductive outcome probabilities, based on number of embryos transferred (ET)

Patient characteristics							If 1 ET		If 2 ET		If 3 ET	
Age	#yrs sub-fertile	#prior IVF cycles	#prior natural live births	Hx endo-metrio-sis? (1= yes)	Hx mis-car-riage? (1= yes)	Hx ectopic? (1= yes)	prob birth	prob mult, if birth	prob birth	prob mult, if birth	prob birth	prob mult, if birth
40	6	1	0	0	0	1	1.13	0.2	3.33	2.37	3.95	3.86
42	7	1	0	1	0	0	4.81	1.11	13.16	11.89	15.33	18.23
31	5	0	0	1	1	0	8.25	1.1	21.24	11.76	24.37	18.04
30	9	2	0	0	0	0	6.73	2.26	17.79	21.74	20.54	31.44
38	3	0	0	0	0	0	5.53	1.89	14.93	18.74	17.33	27.58
25	8	0	0	0	0	0	6.31	3.05	16.81	27.4	19.45	38.39
39	2	0	3	0	0	0	7.24	1.69	18.97	17.09	21.86	25.4
34	8	0	0	0	0	0	9.17	2.46	23.25	23.23	26.58	33.32
32	3	0	0	0	0	0	11.02	2.75	27.09	25.35	30.74	35.92
33	2	0	4	0	0	0	12.24	2.67	29.5	24.75	33.33	35.19

Table 4:

Split sample validation: Predicted probabilities from ForMyOdds.COM compared to actual percent of live births and multiple births in the validation samples

Predicted probability of live birth	Percent of cycles resulting in birth	Predicted probability of multiple birth	Percent of live births resulting in multiples
0.0 to 5.0	3.3	0.0 to 5.0	1.8
5.0 to 9.9	7.2	5.0 to 9.9	8.8
10.0 to 14.9	12.3	10.0 to 14.9	13.5
15.0 to 19.9	17.2	15.0 to 19.9	20.9
20.0 to 24.9	22.6	20.0 to 24.9	25.4
25.0 to 29.9	26.7	25.0 to 29.9	27.2
30.0 or greater	29.7	30.0 to 34.9	33.7
		35.0 to 39.9	37.5
		40.0 or greater	37.8

duration of infertility, number of prior IVF cycles, history of endometriosis, tubal disease, or ectopic pregnancy, and the number of embryos transferred in the index cycle.

Statistical analysis

To determine which variables would be included in the final statistical model, univariate logistic regressions were performed to determine the unadjusted association between each variable and the odds of having a livebirth. For continuous variables (*i.e.*, maternal age), livebirths were graphed by the predictor and fitted to a lowness curve to visualize whether linear or cubic splines might be appropriate. To determine optimal modelling for each predictor variable, several regressions were performed using Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) from which the most appropriate model was selected. Similarly, models were tested with interaction terms between predictor variables and maternal age. Variables were only included in the final predictive model if they were statistically significant.

The final model included maternal age (with a cubic spline at maternal age 29), number of years of involuntary childlessness (continuous), number of previous IVF cycles (with a linear spline at 1 cycle), number of previous natural live births (continuous), history of miscarriage (binary), history of endometriosis (binary), and history of ectopic pregnancy (binary). The number of embryos transferred was included in the model using dummy variables and was limited to 1, 2, or 3 embryos. This configuration was chosen because during the study interval, no more than 3 embryos were permitted to be transferred in any given cycle (in compliance with HFEA policy). The predicted probability of success was thereby tested and structured to be dependent on the number of embryos transferred. The final model was fitted using logistic regression, whereupon the log odds were translated into predicted probabilities of having a livebirth. There was no multicollinearity in the model, as assessed by a variance inflation factor (VIF) test, and a Hosmer-Lemmeshow goodness of fit analysis demonstrated good model fit.

Similar model development methods were used to predict the conditional probability of an IVF cycle resulting in a multiple birth (twins or higher order), given any live birth. We tested the same variable set and selected variables

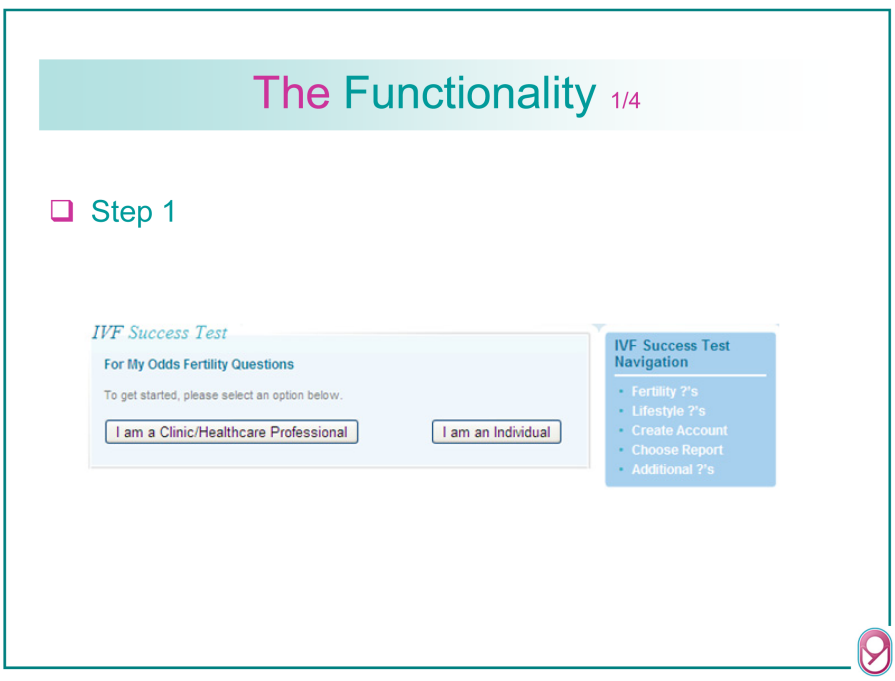

Figure 1.

based on statistical significance using univariate logistic regression models, and thereby determined the best characterization of the predictor variable using AIC and BIC, as previously described. When stratified by number of embryos transferred (1, 2 or 3) in the index cycle, the final multivariate logistic regression model included: maternal age (with a linear spline at maternal age 35), number of years of involuntary childlessness (with a linear spline at 5 years), number of previous IVF cycles, history of miscarriage (binary), history of endometriosis (binary), and history of ectopic pregnancy (binary). Regression diagnostic tests demonstrated no multicollinearity (VIF test) and good model fit (Hosmer-Lemmeshow).

Validation of model

The predictive models so created were validated in a separate sampling of IVF cycles, but was the same for each sample pool. To the appropriate validation sample the regression model was applied, and predicted probabilities were calculated for each IVF cycle. Each model's discrimination was then assessed by measuring the area under the curve of receiver operator characteristics (AUROC) and its calibration by stratifying cycles into 5% increments of predicted probability. Finally, we calculated the true percentage of cycles that resulted in livebirths for each stratum. All analyses were conducted using STATA Version 9. Predicted odds ratios were then summarised more generally in [brackets] in order to protect the proprietary aspects of each respective model.

Results

Clinical characteristics

The ForMyOdds.com predictive 'livebirth' model was developed using a sample of 14,167 IVF cycles, the approximate the capacity of 15 IVF clinics over any given year. Patients in this analysis were women who ranged in age from 20 to 44 (mean±SD=33.8±4.3) years. Just under half of these patients (45.5%) reported previous pregnancy, 19.0% reported a previous natural livebirth, and 5.7% reported a previous IVF-conceived livebirth. A history of ≥1 miscarriages was reported by 3%, and 1% reported a history of ectopic pregnancy. Many patients had a history of endometriosis (41.1%) and 9.5% reported tubal disease. Patients described a wide range of time during which they had been trying unsuccessfully to conceive (range: 0–20; mean±SD= 5.5±3.6 years). The index IVF cycle was their first for 28.3% of patients, the second for 26.6%, the third for 18.9%, and the forth or higher for 26.2% (range: 4–23 cycles).

The predictive 'multiple birth' model was developed using a sample of 13,313 IVF cycles resulting in a live-

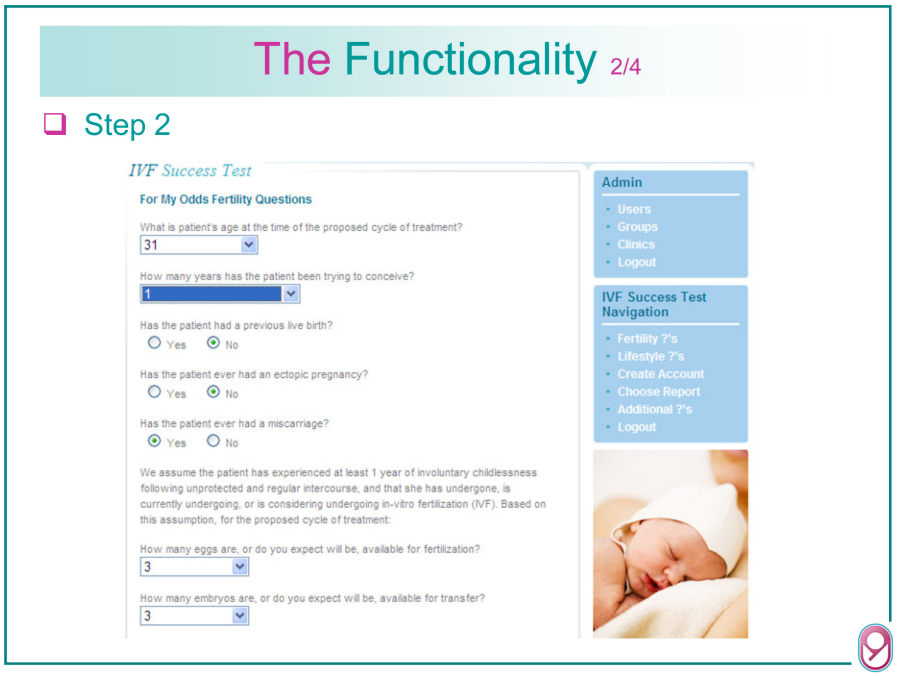

Figure 2.

birth. Because these cycles were selected from the population of 'successful' IVF cycles, patient demographics and clinical characteristics differed slightly. Women were relatively young in this population (mean±SD age=32.9±4.0 years). Under half (45.2%) reported previous pregnancies, 20.9% reported a previous natural live birth, and only 7.3% reported a previous IVF-conceived live birth. Three percent had a history of miscarriage and less than 1% had a history of ectopic pregnancy. Mean ±SD duration of infertility was 5.2±3.3 years. In contrast with the first sample, half of the index cycles were the patients' first (50.5%), 25.0% the second, 12.6% the third, and only 11.9% were the fourth or higher (range 4–23 cycles) cycles, respectively.

Assessment of predictive probability

Overall, 18.9% of cycles resulted in a live birth (13.8% singleton, 4.6% twins, 0.5% triplets). Three sets of quadruplets were reclassified or removed from the dataset by the HFEA and an additional set was removed as on further audit it was found to be entered by one clinic in error. Therefore, triplets were the highest order of multiple births in this analysis. A cycle was *more* likely to result in a live birth if the patient was younger, reported more previous live births, experienced fewer years of being unable to conceive, went through fewer previous IVF cycles, reported no history of miscarriage, ectopic pregnancy, or endometriosis, and if more embryos were transferred (see Table 1).

Amongst cycles that resulted in a livebirth, 72.2% were singleton births, 24.9% were twin births, and 2.9% were triplet births. The factor that most strongly affected the conditional probability of having a multiple birth was having 2 or 3 embryos transferred. Births were less likely to be multiple if the patient was older, experienced more years of not being able to conceive, reported more previous cycles of IVF, or reported a history of miscarriage, ectopic pregnancy, or endometriosis (see Table 2). Table 3 presents examples of cases from the HFEA registry and their predicted probability of birth and multiple births.

Both 'livebirth' and 'multiple births' models showed good discrimination, with AUROC's of 0.635 and 0.618, respectively. Also, both models demonstrated very good calibration (see Table 4). There was a slightly better calibration in the 'livebirth' as compared with 'multiple births' models, and slightly diminished calibration at the ceiling of each model, compared to the lower and mid-range of predicted probabilities. This means that the model is most accurate for the general population who have a low to average chance of achieving a livebirth. The "livebirths" model slightly overestimates the livebirth rate among women who were predicted to have a 30% or greater chance of a livebirth. Similarly, the "multiple

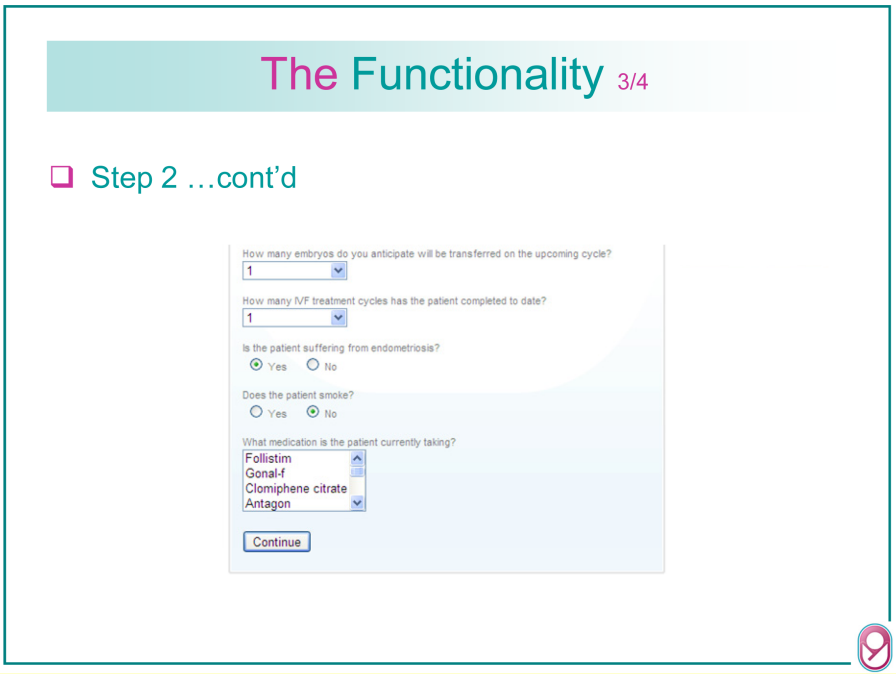

Figure 3.

births" model slightly overestimates the chance of actually delivering multiples among the population of women with a 40% or higher predicted probability of multiple births. Among the mid-range, the model slightly underestimates the chance of a multiple birth. Nonetheless, where differences exist between actual and predicted probabilities, the variation remained <3% (in most instances, it was much less than this; see Table 4).

Electronic access to modelling (via internet)

These models have been developed into a openly available online tool that is intended to be used by clinicians to assist patients understand their individual likelihood of IVF success and, indeed, multiple births before undergoing IVF. This website was commissioned in January 2008 as a patient education tool, to help in the decision to undergo IVF either for the first time, whether to continue with additional cycles of IVF following a failed cycle, the consequences of delaying treatment (or, stated another way, the benefits of expeditious treatment) and how many embryos one should request to be transferred on each successive cycle. Figures 1–5 show screen shots of the sequential steps to be performed by clinicians and other healthcare personnel, in order to arrive at results that are, at the end of each analysis, personalised to the individual circumstances of every IVF patient. The 'Fast Forwarding' feature of ForMyOdds.COM illustrated in Figure 4 allows for predictions to be made long before the patient undergoes additional treatments. Under such circumstances, the declining probability of conception is highlighted over time, underscoring the importance of early intervention. The models were further (externally) validated in *ad hoc* analyses conducted at The Sims Institute (Dublin) and at University of Michigan (Ann Arbor) to ensure consistency with current medical practice. This validation provided a key development feature to our models; namely, the inclusion of a screenshot at the end of each 'IVF Success Test' that asks whether the clinician agrees or disagrees with the predicted odds (Figure 5). Using ForMyOdds.COM, clinicians can rapidly show patients their individual predicted probabilities that depend in great part on how many embryos are transferred. It is anticipated that this process can help guide the conversation on embryo transfer and manage realistic expectations concerning IVF success against the risks of multiple births and failing to complete a family in the expected timeframe.

Discussion

ForMyOdds.COM predicts individualised chances of achieving a livebirth and multiple births using formulae that were developed using the largest available population-based dataset of IVF treatments and outcomes. Additionally, the software calculates the chances of livebirths and

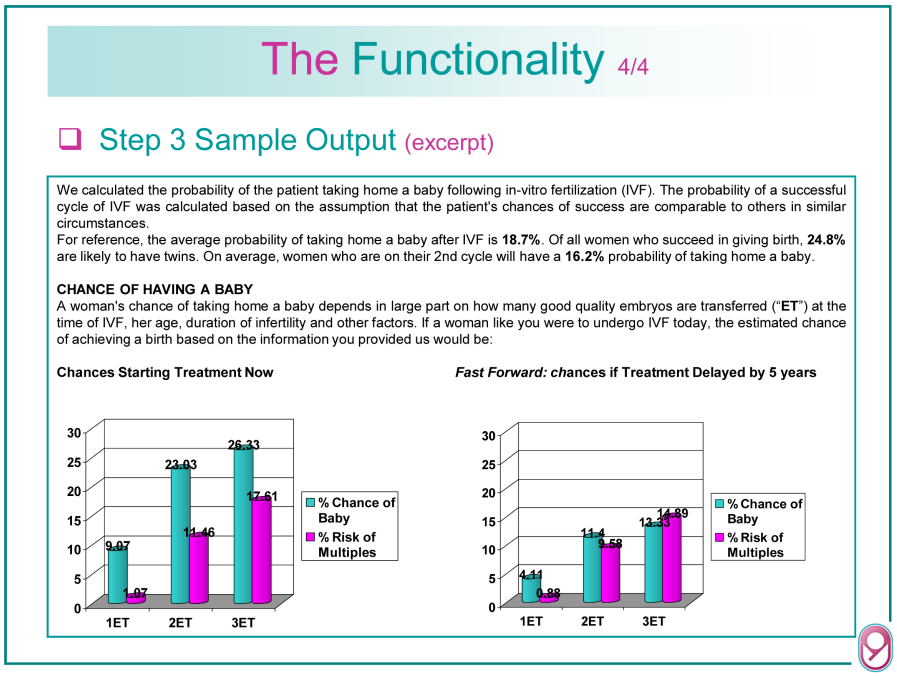

Figure 4.

multiple births using a 'Fast Forwarding' function, at defined future time points. First reported in July 2008 [15], this approach represents the first time an *ex ante* approach was utilised to predict IVF treatment success. It is anticipated that clinicians and patients alike may benefit from improved accuracy and transparency in predicting reproductive outcome.

As a counselling aid, this approach educates patients about the impact of age on reproductive outcome, and encourages early evaluation of fertility potential. Given that IVF success is well known to be age-dependent [16–18], patients who seek such treatments may be under financial, clinical, or time pressures that might otherwise interfere with the possibility of receiving early intervention. Indeed, the results of our analysis support contemporary findings that livebirth rate increases significantly when additional embryos are transferred to certain populations of women [19]. Yet, in some cases (*i.e.*, female age 33, infertility duration of 2yrs, no prior IVF, 4 previous livebirths), doubling the livebirth rate with an extra embryo comes at the cost of a 10–fold increase in the risk of multiple gestation (predicted probability of livebirth = 12.2% if 1 embryo is transferred vs. 29.5% if 2 embryos are transferred; predicted probability for multiple gestation = 2.7% if 1 embryo is transferred vs. 24.8% if 2 embryos are transferred). Moreover, including a third embryo at transfer to individuals who would otherwise have only received two, resulted in only a small increase in odds of a livebirth at the expense of a substantial increase in the predicted probability of multiple gestation. Interestingly, this was not predicted to be true in all clinical circumstances, and for the small percentage of patients who might otherwise not have attained a livebirth with single embryo transfer, the trade-off needs to be understood in consultation with their doctor according to individual patient preference. Our results highlight why individualised statistics are essential for counselling, as actual IVF success depends on numerous individual factors that are impossible ascertain from aggregate "success rate" data generally available from clinics.

As a variation of disease progression modelling for description of impact of age on reproductive outcome, ForMyOdds.COM also presents the consequences of delaying treatment by 1 year or 5 years, and places the importance of early intervention in sharp relief. When presented as tangible odds of success, it is hoped that the patient may seek services earlier than they might have done if they were unaware of the consequences of continuing to delay parenthood. As a clinical research tool, ForMyOdds.COM also collects anonymised doctor- and/or patient-reported usage data concerning the specific drugs being prescribed. It is hoped that this information can be used for research purposes to examine case-mix patterns and to establish additional links between treat-

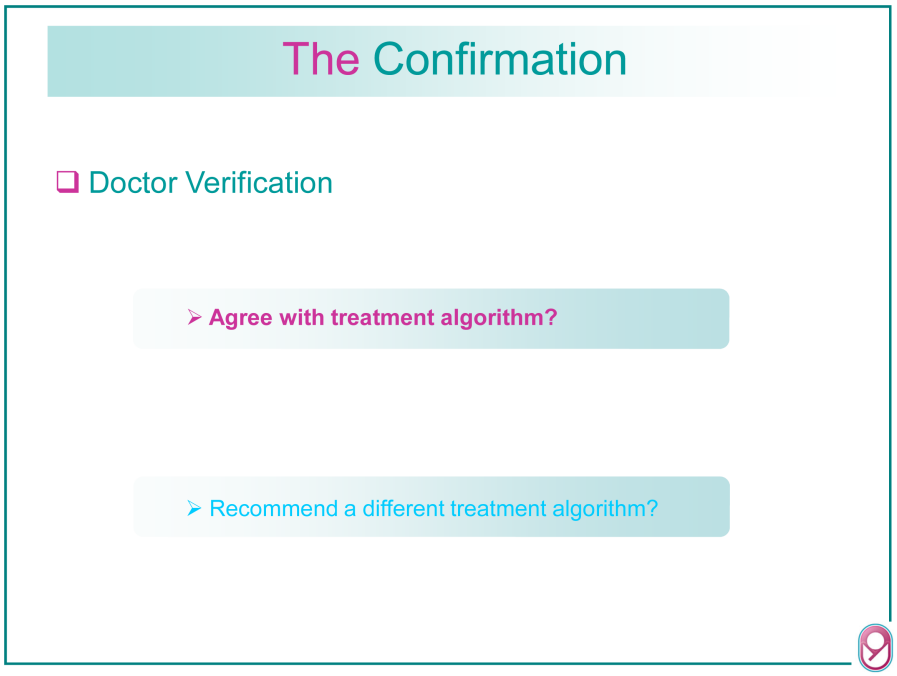

Figure 5.

ments and outcomes. Not surprisingly, the results of this study indicate that the success of IVF is greatest in younger women during their first cycle of treatment. This is likely because first presenters are more likely to be part of the more fertile population as compared with those with a long history of inability to conceive [3].

Although this approach demonstrates the value of personalised information, the models do have limitations. For example, predictions generated from this model could not present the variability of individual results (*e.g.* 95% confidence intervals). As such, predictions of odds are presented as average estimates only. In our study population, 18.9% of IVF cycles resulted in a livebirth. Increasing the number of embryos transferred predictably increased this probability, but at a heightened risk of multiple births. Such a balance is invariably weighted differently according to various patient and treatment cases, and should not be generalised according to just one discriminating variable (*e.g.*, age), but rather according to the interaction among all relevant variables. Moreover, the model cannot be generalized to women over age 44, because the HFEA dataset did not include women above this age. Finally, the time scale for the database (1991–1998) is such that it predated the HFEA directive to limit the number of embryos transferred to 2 embryos per cycle in women 40 years of age and younger. As such, different treatment policies existed in the UK during the time period of analysis with only a minority of clinics having a 'two embryo transfer policy' and very few clinics performing elective single embryo transfer. To this end, our predictions based on single embryo transfers must be regarded with a certain degree of caution, as it was assumed that the vast majority of these were non-elective single embryo transfers (*i.e.*, only one embryo was available for transfer, an *a priori* poor prognostic indicator).

It should be acknowledged that the HFEA definition for "livebirth" incorporates the neonatal period of 28d. Thus, the model's prediction of this outcome should be considered according to this taxonomy and explained carefully to all users. Some countries may not reliably register babies who die within the first 24h of birth, or may place limits based on birth weight or gestational age in vital statistics [20]. However, we consider this difference as a refinement to the extent that IVF patients would actually prefer to access odds that their baby will be born alive and healthy (not just alive *only*), an endpoint which this model uniquely delivers.

Neonatal survival has generally improved since the time of the HFEA data contributing to this study, and specific neonatal outcomes may vary according to birth multiplicity, between hospitals, with certain IVF techniques, or by other important characteristics not currently embraced by this model. For these reasons, our model's accuracy in

predicting IVF birth outcomes may vary. To address this limitation, the model can be modified to incorporate local IVF and neonatal outcomes data and prospectively improve the model's predictive performance on an ongoing basis. And finally, while this dataset is from 1991–1998, IVF policy changes that have led to changes in multiple birth rates in the UK and USA are not expected to affect the accuracy of model outputs provided that the inputs are within realistic ranges used in model development and validation.

Conclusions

Patients are increasingly becoming active participants in, rather than subjects of, medical treatments. The results of the present study support algorithmic and personalized approaches to health care delivery generally, with a topic such as IVF providing an early test-case. When used for predictive informational purposes, it is hoped that the methodology behind ForMyOdds.com may be generalised to other treatments and diseases for which predictive weightings have been reliably studied and externally validated. It is further hoped that ForMyOdds.com will assist in presenting numerically-based reasons for patients demanding early diagnosis and optimal treatments for their individual circumstances.

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