

## **Discussion**

During the football season 2013-2014, 10.4 % of female players and 14.8 % of male players reported an injury preventing them from football practice for more than 15 days. Our definition is slightly different from the time-loss categories definition suggested by Fuller [13], but it is justified by the fact that it represents a clinical threshold for which diagnostic and therapeutic interventions are generally more invasive in a nonprofessional setting with little medical coverage. The observed injuries concerned mainly the knees and the thighs, respectively, with a clear difference related to the sex. In females the predominant injury types were capsuloligamentous lesions whereas in males the main recorded lesions were muscle injuries of the thigh.

These percentages are close to those observed in a large Spanish study on male amateur football players, showing that 11 % of athletes aged under 30 had a physical complaint resulting from a football match or training session during the season 2010-2011 [12]. Nevertheless, they recorded all injuries irrespective of the medical attention or time loss from football activities. It appears therefore that the percentage of overall injuries (i.e. including slight and mild injuries with time loss < 15 days) in Luxembourg is probably higher than the percentage observed in Spain. The injury incidence observed in our study is quite similar between females and males (0.7 and 0.6 injuries/1000 h, respectively). It is close to that observed in male and female elite football players (0.7 injuries/1000 h) in Sweden [6] and to the incidence of severe injuries (time loss > 28 days) observed in female teenager football players (1.1 injuries/1000 h) in Denmark [2]. More injuries have been observed in male than female players in Belgium, but the latter had a higher incidence of severe injuries [14].

Our study shows that moderate to severe injuries occur more often during competition compared to training (71 % for females, 59 % for males). Competition is therefore a more risky context regarding injuries, as suggested by numerous other studies [4, 5]. This illustrates the lower stakes related to the training context, but could also reflect the education of the coaches who try to avoid situations that put their players at risk. Furthermore, it has been shown that the incidence of moderate to severe injuries is higher for amateurs than professionals [14, 15]. A possible explanation may be that the teams are smaller in amateur football and lead to fewer options to substitute injured players or players who are more at risk to sustain an injury. On the other hand, players with low football participation (< 1 hour per week) have a higher injury risk compared with players participating more frequently [2]. The percentages of injury recurrence observed in our study during the season 2013-2014 (12 % in females and 27 % in males) are close to those observed in competition (maximum observed = 22 %) [16]. However, they are slightly lower than those observed overall in Denmark (30 %) and Sweden (24 %) [17]. The recurrence of the injuries may suggest a maladjusted management of the previous injury with a precipitated return to play.

The injuries concerned mainly the lower limb, both in female and male football players. In female football, it has been shown that lower extremity injuries are related to greater BMI [18]. In our study, we observed a tendency for greater BMI in injured female players. Nevertheless, the group of injured female players was quite small ( $n = 13$ ) giving rise to a low statistical power. Capsuloligamentous knee injuries, including ACL tears, were the most frequently recorded injury type in female football players. It is well known that non-contact ACL injuries are a major concern in female football, the injury risk being 2-3 times higher as compared to male football [19]. This is mainly due to internal risk factors (anatomical and structural, genetic, hormonal, neuromuscular and biomechanical) [20]. It has been shown that up to 72 % of these non-contact ACL injuries are preventable [21]. Hence, reducing the number of non-contact ACL injuries by introducing prevention programmes should be a primary target in Luxembourgish female football. Conversely, musculotendinous injuries of the thigh were the main recorded type of lesion in male football players during the season 2013-2014. These observations are in accordance with the data of the literature [12, 17]. This type of lesion may explain the higher incidence of recurrences observed in male compared to female football players, especially if players and coaches do not respect the medical prescription and precipitate the return to play. Again, it has been shown that many of these lesions are preventable through easily implementable training programmes [22]. Indeed, several sports injury prevention programmes have been developed and implemented to reduce the occurrence and the severity of injuries in football (e.g. FIFA 11+ programme) [11, 23, 24]. These programmes include stretching, muscle strengthening, balance exercises, sports-specific agility drills and landing techniques. Despite an unsuccessful attempt by the FLF to implement the FIFA 11+ programme in 2009 (personal communication of R. Huberty and H. Mausen), it is critical to try again to generalise such a programme in Luxembourgish football teams. However, such an endeavour is challenging, due to the low medical and physiotherapeutic coverage in the Luxembourgish teams, particularly in the female football. This is in strong contrast with other top-level leagues, in which generally more than 5 local stakeholders (mainly physiotherapists) are involved in the design and implementation of injury prevention programmes [25].

The number of recorded injuries is probably underestimated in our study due to a possible lack of compliance of the designated health expert, players' involvement and the above-mentioned injury definition. This first issue could be addressed in the future with the use of the Training and Injury Prevention Platform for Sports (TIPPS) for data collection [26]. The TIPPS is an internet-based electronic surveillance system allowing for easy recording of daily information by the athletes via personal access codes. The athletes upload volume and intensity of each sport session and the sports injuries on their TIPPS account. All football players should be sensitized for TIPPS. Further studies using the TIPPS are

needed to evaluate the effect of a preventive programme in the Luxembourgish football teams.

In conclusion, this study showed that injuries in top-level Luxembourgish football players were mainly located in the lower limbs. Knees and thighs were the predominantly concerned anatomic areas in female and male players, respectively. The injuries encountered in the Grand-Duchy of Luxembourg are similar to those observed in other countries. Many of them are preventable through the implementation of specific injury prevention programmes. Introducing a systematic medical coverage and developing an injury prevention strategy like the “FIFA 11+” may rapidly lead to a significant reduction of injuries in Luxembourg’s highest football leagues.

## **Acknowledgement**

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# **Promotion de l'activité physique comme moyen de prévention secondaire chez des patients atteints de maladies chroniques : état des lieux au Grand-Duché de Luxembourg**

## **Physical activity promotion for secondary prevention in patients with non-communicable diseases: the situation in the Grand-Duchy of Luxembourg**

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### **Abstract**

The regular practice of physical activities has health benefits in healthy subjects (primary prevention) and in patients with non-communicable diseases (secondary prevention). This study aimed to perform a stocktaking of the physical activities programs for patients or individuals at risk in the Grand-Duchy of Luxembourg.

The organizations offering therapeutic physical activities (TPA) have been investigated. Eleven groups offering TPA adapted to different non-communicable diseases were characterized by their costs, instructors, participants and potential participants. These groups were divided into five main categories: cardiology,

neurology, obesity, oncology, and orthopedics. During on-site meetings, 41 professionals, 192 participants and 34 potential participants have been interviewed during the period September 2013 to April 2014.

The results show that about 40 hours of TPA, 17 hours of which in cardiology, are currently proposed every week, except during school holidays. The main TPA are gymnastics, aerobics, swimming, Nordic walking, cycling, and resistance training. The national coverage is quite low, especially for obesity, neurology and orthopedics. The costs is mainly related to the human resources, the gym being often borrowed but rarely available during school holidays. Between 200 and 400 individuals participate in the TPA. The average number of participants per hour is  $8.9 (\pm 5.1)$ , which represents only 50 % of the maximal capacity estimated by the instructors ( $18.0 \pm 8.2$  participants per hour). The recruitment process is different according to the groups but the medical doctors and the physiotherapists are mainly involved in this process. However, the majority of the potential participants were not aware of the existence of the groups.

The existence of these groups is a positive point, since it contributes to compensate for the current lack of concrete action of the public and private authorities. However, the current TPA offer is clearly insufficient. The groups are frail, on the one hand because their future relies exclusively upon the idealism of a few key actors, and on the other hand because the participation rate is low. This low rate is related to a lack of information and to organizational constraints. However, the public health action initiated by these groups should be perpetuated and strengthened with a better structuration and professionalization. Finally, the increase of the number of participants remains the main objective.

**Keywords:** secondary prevention, physical activities, non-communicable diseases.

## Résumé

La pratique régulière d'activités physiques a des effets bénéfiques sur la santé des sujets sains (prévention primaire) et des patients atteints de certaines maladies chroniques (prévention secondaire). Cette étude vise à faire un inventaire des programmes d'activités physiques menés avec des patients ou des personnes à risque au Grand-Duché de Luxembourg.

Les structures proposant des activités physiques thérapeutiques (APT) ont été recherchées et analysées. Ainsi, onze groupes proposant des cours d'APT adaptés à différentes maladies chroniques ont été caractérisés par leurs coûts, leurs moniteurs, leurs bénéficiaires actuels et leurs bénéficiaires potentiels. Ces groupes ont été répartis en cinq catégories majeures : cardiologie, neurologie, obésité, oncologie, et orthopédie. Lors des rencontres sur sites, 41 professionnels,

192 bénéficiaires et 34 bénéficiaires potentiels ont été auditionnés de septembre 2013 à avril 2014.

Les résultats montrent qu'environ 40 heures d'APT, dont 17 heures en cardiologie, sont actuellement proposées chaque semaine en dehors des vacances scolaires. Les principales APT sont la gymnastique, l'aquagym, la natation, la marche nordique, le cyclisme, et la musculation. La couverture nationale est assez faible en particulier en obésité, neurologie et orthopédie. Les coûts sont essentiellement liés aux ressources humaines, les locaux étant souvent prêtés, quoique rarement disponibles pendant les vacances scolaires. Entre 200 et 400 bénéficiaires participent aux cours d'APT. Le nombre moyen de bénéficiaires par heure est de 8,9 ( $\pm 5,1$ ), ce qui représente seulement 50 % de la capacité maximale d'accueil estimée par les moniteurs ( $18,0 \pm 8,2$  bénéficiaires par heure). Le mode de recrutement varie selon les groupes mais les médecins et les kinésithérapeutes jouent un rôle majeur. Cependant, la majorité des bénéficiaires potentiels n'avaient préalablement pas connaissance de l'existence des groupes.

L'existence de ces groupes, qui permet de pallier l'absence actuelle d'action concrète des pouvoirs publics et privés, est un point positif mais elle n'est néanmoins pas suffisante ni satisfaisante. Les groupes sont fragiles d'une part car leur avenir dépend exclusivement de l'idéalisme de quelques acteurs clés, et d'autre part car la participation est faible. Cette faible participation est liée à un manque d'informations et aux contraintes organisationnelles. Aussi, l'action de santé publique entreprise par ces groupes devrait être pérennisée et renforcée par une meilleure structuration et une professionnalisation. Enfin, l'augmentation du nombre de bénéficiaires reste l'objectif principal.

**Mots-clés :** prévention secondaire, activités physiques, maladies chroniques.

## **Introduction**

La connaissance des effets bénéfiques de la pratique régulière d'exercice pour la promotion de la santé et le traitement des maladies n'est pas récente. Il y a 4500 ans en Chine, des exercices physiques étaient déjà organisés dans le but de promouvoir la santé. De même, Hippocrate et Gallien reconnaissaient (il y a 2500 ans) également l'intérêt de faire des exercices dans le but d'obtenir un bénéfice sur la santé et la qualité de vie [1]. Ainsi, une légère augmentation de la dépense énergétique (1000 kcal par semaine) liée à la pratique d'une activité physique est associée à une diminution de la mortalité d'environ 20 % [2]. Les activités physiques jouent un rôle majeur dans la prolongation de la durée de la vie en bonne santé. En effet, il existe des preuves de l'efficacité de la prescription d'exercices pour la prévention du cancer, de la dépression et des maladies de type cardiaque, pulmonaire, métabolique, musculaire, osseux et articulaire [3]. De plus, les activités physiques sont tellement bénéfiques pour la santé qu'elles devraient être considérées comme un médicament [4]. Elles peuvent être considérées comme un traitement pour des maladies déjà installées [3-6].

Afin de promouvoir les activités physiques thérapeutiques, différents modèles ont été créés de par le monde et dépendent du contexte local dans lequel ils sont implantés. Par exemple, le modèle allemand a développé le programme « Sport Pro Gesundheit » qui permet d'attribuer les labels « Sport Pro Gesundheit » ou « Sport Pro Fitness » aux groupes et aux centres de fitness qui promeuvent l'activité physique comme moyen de protection de la santé. Ces structures labellisées sont répertoriées sur un site Internet qui fournit par ailleurs des fiches techniques permettant de choisir les activités physiques thérapeutiques en fonction de la pathologie. Ce programme qui est partiellement financé par la caisse de santé met également en place des formations à destination des professionnels de la santé. Ces formations permettent d'avoir une connaissance précise des activités physiques spécifiques en fonction des maladies et des pathologies.

Par ailleurs, Exercise is Medicine® Australia (inspiré de la version américaine Exercise is Medicine®) a été développé pour faire de la prescription et de la promotion des activités physiques un standard dans la prévention et le traitement des maladies pour tous les patients en Australie. Exercise is Medicine® Australia travaille avec l'ensemble des professionnels de la santé (médecins, kinésithérapeutes, infirmiers/infirmières, etc.) afin de faire une évaluation de la pratique d'activités physiques lors de chaque consultation des patients. Ainsi, des outils sont proposés pour conseiller les patients dans le choix d'une activité physique et/ou pour leur donner des informations relatives au lien existant entre santé et activité physique.

Enfin, le modèle français attribue un label Sport-Santé aux structures promouvant les activités physiques thérapeutiques. Les bénéficiaires participent à un cycle éducatif avant d'intégrer une structure labellisée Sport-Santé. Ainsi, les médecins

peuvent conseiller leurs patients sains ou atteints de pathologies chroniques de gravité modérée dans le but de pratiquer une activité physique pour améliorer leur santé. Les personnes adressées par leur médecin sont accompagnées pendant un à deux mois (11 séances) par un intervenant diplômé et spécialement formé. La pratique s'effectue en groupe de cinq à huit personnes. À l'issue de cette période d'accompagnement, les personnes sont orientées par l'intervenant vers une structure labélisée Sport-Santé [7]. Tous ces modèles offrent la possibilité aux médecins de prescrire des activités physiques à leurs patients en utilisant une ordonnance-type disponible sur les sites Internet.

Cette étude visait à faire un inventaire exhaustif des programmes sportifs structurés et menés avec des patients ou des personnes à risque dans le cadre de la promotion de l'activité physique comme mesure de protection de la santé au Grand-Duché de Luxembourg. Elle visait également à évaluer les besoins et les attentes de ce secteur. Il était alors nécessaire de faire un état des lieux au Grand-Duché de Luxembourg des dispositifs mis en place permettant de dispenser des activités physiques ou sportives dans le but de faire des préventions secondaire et tertiaire.

## **Matériels et Méthodes**

### ***Critères d'inclusion des groupes***

Onze groupes proposent des activités physiques thérapeutiques toute l'année à des personnes atteintes de maladies ou de pathologies. Ces 11 groupes ont été évalués dans la période de septembre 2013 à avril 2014 et agrégés dans 5 catégories (Tableau 1) : cardiologie (1 groupe), neurologie (3 groupes), obésité (2 groupes), oncologie (3 groupes), orthopédie (2 groupes). Les bénéficiaires de ces groupes sont en phase II (amélioration des performances de certaines fonctions en lien avec une maladie ou une pathologie donnée) ou en phase III (maintien des performances) de rééducation. Ces 11 groupes ont une visée thérapeutique et la compétition n'est pas une finalité. Les groupes qui ont un but de compétition et ceux qui proposent des actions limitées dans le temps (par ex. cures thermales, etc.) n'ont pas été analysés.

**Tableau 1.** Groupes d'activités physiques thérapeutiques en fonction des pathologies

Pathologies	Nom des groupes
Cardiologie	Association Luxembourgeoise des Groupes Sportifs pour Cardiaques (ALGSC) <a href="http://www.algsc.lu">http://www.algsc.lu</a>
Neurologie	Association Luxembourgeoise d'aide pour les personnes Atteintes de maladies Neuromusculaires et de maladies rares (ALAN) <a href="http://www.alan.lu">http://www.alan.lu</a>
	Association Parkinson Luxembourg <a href="http://www.parkinsonlux.lu">http://www.parkinsonlux.lu</a>
	Ligue luxembourgeoise de la sclérose en plaques (MS Luxembourg) <a href="http://www.msweb.lu">http://www.msweb.lu</a>
Obésité	Groupe sportif Obésité <a href="http://www.chl.lu/clinique-obesite/clinique-du-sport-clinique-de-obesite">http://www.chl.lu/clinique-obesite/clinique-du-sport-clinique-de-obesite</a>
	Movin' Kids <a href="http://www.vdl.lu/sportspourtous.html">http://www.vdl.lu/sportspourtous.html</a>
Oncologie	Association Luxembourgeoise des Groupes Sportifs Oncologiques (ALGSO) <a href="http://www.sportifsoncologiques.lu">http://www.sportifsoncologiques.lu</a>
	Fondation Cancer <a href="http://www.cancer.lu">http://www.cancer.lu</a>
	Fondatioun Kriibskrank Kanner (cours proposés en partenariat avec ALGSO) <a href="http://www.fondatioun.lu">http://www.fondatioun.lu</a>
Orthopédie	Groupe sportif luxembourgeois pour hanche et genou <a href="http://www.medecinedusport-chl.lu/Groupes_sportifs/groupes_sportifs.html">http://www.medecinedusport-chl.lu/Groupes_sportifs/groupes_sportifs.html</a>
	Ligue luxembourgeoise contre le rhumatisme

### ***Caractérisation des groupes***

Les groupes ont été caractérisés par le nombre d'heures hebdomadaires d'activités physiques thérapeutiques, leur âge, la disponibilité et le coût des locaux, le coût des ressources humaines pour encadrer les cours et les recettes liées aux cotisations des bénéficiaires. De plus, le nombre de bénéficiaires par heure a été observé pour chaque groupe. Par ailleurs, 41 personnes s'occupant des groupes ont été rencontrées. Ces moniteurs ont estimé le nombre maximal de bénéficiaires par heure qu'ils pourraient encadrer en conservant une sécurité suffisante. Enfin, la formation des moniteurs et les mesures de sécurité mises en place ont été analysées.

### ***Caractérisation des bénéficiaires***

De plus, 192 bénéficiaires ont été rencontrés et caractérisés selon l'âge, l'ancienneté de participation dans les groupes, le sexe, le type de recrutement, la distance entre leur domicile et le lieu des cours, la pratique d'activités physiques actuelle et passée.

### ***Caractérisation des bénéficiaires potentiels***

Enfin, 34 bénéficiaires potentiels qui ont subi une intervention chirurgicale dans le but de poser une prothèse de hanche ou de genou ont répondu à un questionnaire concernant la volonté de participer à un groupe d'activités physiques thérapeutiques. Ces bénéficiaires potentiels ont été caractérisés selon l'âge, le sexe, la connaissance de l'offre, le souhait de participer aux cours, la convenance du lieu des cours, la distance entre leur domicile et le lieu des cours,

la convenance du montant de la cotisation et la pratique d'activités physiques.

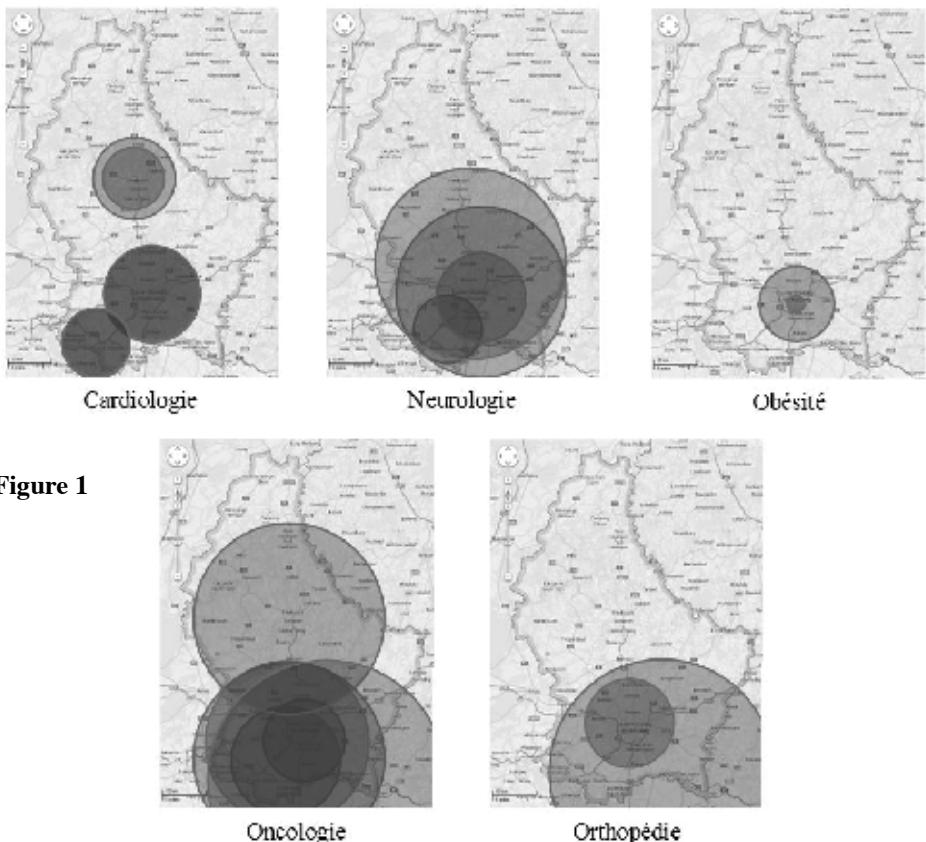
### ***Analyse statistique***

Les données ont été anonymisées et ont été analysées par des statistiques descriptives. Ainsi, les variables quantitatives sont exprimées par la moyenne et l'écart type ( $\sigma$ ) et les variables qualitatives sont exprimées par le nombre (n) et le pourcentage (%).

## **Résultats**

### ***Les groupes***

Les caractéristiques des groupes des 5 catégories sont présentées dans le Tableau 2. La plupart des groupes sont âgés de moins de 10 ans, le groupe le plus ancien étant celui pour les personnes cardiaques. Chaque semaine (sauf pendant les vacances scolaires), environ 40 heures d'activités physiques thérapeutiques sont actuellement proposées par les différents groupes. A eux seuls, les groupes sportifs pour cardiaques proposent plus de 17 heures d'activités physiques thérapeutiques. Les différentes activités proposées, qui sont réparties en trois sections (sud, centre, nord) (Figure 1), sont la gymnastique, la natation, l'aquagym, la marche nordique, et le cyclisme. Les bénéficiaires atteints de cancer peuvent pratiquer plus de 11 heures d'activités physiques par semaine (gymnastique, aquagym, musculation, marche nordique). Cette offre couvre la majeure partie du territoire. Enfin, l'offre proposée en obésité, neurologie et orthopédie est limitée et la couverture nationale de ces groupes est particulièrement faible. Les coûts liés aux ressources humaines (moniteurs, kinésithérapeutes, infirmiers, médecins) sont principalement liés à l'étendue de l'offre. Les groupes sont gérés par des comités. Les cours sont adaptés à la population rencontrée quels que soient les groupes. Par exemple, des exercices mobilisant principalement les membres supérieurs sont réalisés dans un groupe des femmes qui ont eu un cancer du sein. De plus, des groupes de niveaux sont proposés lorsque la masse critique de bénéficiaires pour ouvrir un groupe est atteinte.



**Figure 1**

*Figure 1. Couverture nationale des différents groupes. Chaque cercle indique la distance moyenne entre le domicile du bénéficiaire et le lieu où le cours d'activités physiques thérapeutiques est proposé.*

## *Les coûts*

Afin de pouvoir assurer les 17 heures hebdomadaires de cours d'activités physiques thérapeutiques, les groupes sportifs pour cardiaques ont besoin de plus de 100 000 € par an (Tableau 2). Ces coûts s'expliquent par la présence de moniteurs, d'infirmiers ou d'infirmières et de médecins. Les coûts pour le personnel sont estimés à un peu plus de 70 000 € par an pour les autres groupes. La rémunération des moniteurs varient de 35 à 100 € par heure. Les cotisations des bénéficiaires permettent de couvrir 18% des coûts des ressources humaines. Cependant, le montant des cotisations est variable selon les groupes, c'est-à-dire de la gratuité à 100 € pour 10 cours. Par ailleurs, la location des locaux et l'achat de matériel augmentent les coûts de certains groupes. Les locaux sont toutefois gracieusement prêtés pour la majorité des groupes. En effet, de nombreux cours sont organisés dans les structures sportives d'établissements scolaires dont la

disponibilité a été rendue possible grâce à des initiatives personnelles. L'accès à ces structures n'est cependant pas possible pendant les vacances scolaires. De plus, les horaires de disponibilité sont dépendants de l'utilisation des structures par les écoles.

**Tableau 2.** Offre, âge du groupe, estimation du coût, estimation des cotisations, participation observée et participation maximale estimée par les moniteurs en fonction des pathologies.

--- : moyenne ou total non calculé.

Pathologies	Ancienneté du groupe (ans) Moyenne ( $\sigma$ )	Offre (h/semaine)	Coût (€/an)	Cotisation (€/an)	Participation (n/h) Moyenne ( $\sigma$ )	Participation maximale (n/h) Moyenne ( $\sigma$ )
Cardiologie	19,9 (5,8)	17,00	110 705	21 390	12,0 (6,2)	24,5 (9,2)
Neurologie	4,0 (1,1)	6,00	28 000	5 400	6,6 (4,4)	11,9 (4,9)
Obésité	2,4 (0,8)	2,50	6 400	2 400	7,6 (6,1)	17,5 (10,6)
Oncologie	6,2 (3,7)	11,25	30 000	2 000	6,8 (3,7)	9,1 (4,1)
Orthopédie	15,5 (12,1)	3,00	7 700	2 480	10,3 (0,4)	20,0 (5,6)
Total	---	39,75	182 805	33 670	---	---
Moyenne	10,8 (8,6)	---	---	---	8,9 (5,1)	18,0 (8,2)

### ***Les moniteurs***

L'hétérogénéité des formations est importante (par ex. : kinésithérapeute, maître-nageur, thérapeute du sport) et la formation spécifique n'est pas systématique. En effet, les moniteurs qui ont bénéficié de formation spécifique sont rares. Des moniteurs (orthopédie, obésité, et oncologie) ont participé à certaines formations spécifiques qui ont toutes eu lieu en Allemagne. Les moniteurs en cardiologie ont bénéficié, pour la plupart, à des formations de rééducation cardiaque au sein du Centre Hospitalier de Luxembourg. Enfin, certains moniteurs se sont formés empiriquement au contact des bénéficiaires qui connaissent les limites de leurs possibilités corporelles. Afin d'assurer la sécurité, des médecins et des infirmiers sont présents, en particulier en cardiologie où ils mesurent la tension artérielle et la fréquence cardiaque. Pour l'ensemble des activités aquatiques, un maître-nageur assure exclusivement la surveillance. Enfin, le matériel de secourisme est disponible pour la plupart des cours.

### ***La participation***

Entre 200 et 400 bénéficiaires participent aux cours d'activités physiques thérapeutiques. Aucun groupe n'atteint les capacités maximales d'accueil estimées par les moniteurs (Tableau 2). Le taux moyen de participation des bénéficiaires ( $8,9 \pm 5,1$  bénéficiaires par heure) est d'environ 50 % inférieur à celui de la capacité maximale d'accueil ( $18,0 \pm 8,2$  bénéficiaires par heure). Chaque groupe pourrait donc accueillir une dizaine de bénéficiaires supplémentaires.

## **Les bénéficiaires**

L'âge des bénéficiaires varie selon les pathologies. Les bénéficiaires avec des problèmes orthopédiques (hanche, genou, arthrose, rhumatisme) sont les plus âgés (Tableau 3), ceux avec des problèmes de poids les plus jeunes. Trois cours sont proposés exclusivement pour des enfants/adolescents (neurologie, obésité et oncologie). L'ancienneté moyenne de participation est de  $5,3 \pm 3,6$  ans alors que la moyenne d'âge des groupes est de  $10,8 \pm 8,6$  ans, indiquant qu'il y a peu de nouveaux bénéficiaires.

**Tableau 3.** Nombre de bénéficiaires interrogés, âge, ancienneté dans le groupe et sexe en fonction des pathologies. --- : moyenne ou total non calculé.

Pathologies	Bénéficiaires (n)	Âge (ans) Moyenne ( $\sigma$ )	Ancienneté (ans) Moyenne ( $\sigma$ )	Sexe (% de femmes)
Cardiologie	76	66,3 (8,6)	7,8 (5,3)	15,7
Neurologie	25	45,9 (8,8)	2,3 (1,2)	56,0
Obésité	17	16,7 (3,9)	1,4 (0,5)	54,5
Oncologie	46	59,4 (8,7)	3,6 (2,4)	80,8
Orthopédie	28	68,6 (8,7)	5,8 (4,5)	78,6
Total	192	---	---	---
Moyenne	---	58,2 (8,3)	5,3 (3,6)	48,3

Le sexe varie également en fonction des pathologies, les femmes étant majoritaires en oncologie et en orthopédie. Les hommes sont majoritaires en cardiologie.

La distance entre le domicile des bénéficiaires et le lieu où les cours sont proposés est en moyenne de  $12 \pm 7$  km (Figure 1). La couverture nationale varie selon les groupes. Les groupes sportifs en cardiologie sont implantés au Nord, au Centre et au Sud. En neurologie, les cours sont proposés principalement dans le Sud et le Centre du pays. Les cours proposés pour les bénéficiaires obèses sont uniquement disponibles au Centre du pays. Pour l'oncologie, la couverture nationale est importante, à l'exception de l'extrême Nord et de l'extrême Est du pays. Enfin, les cours sont principalement proposés dans le Centre et le Sud-Est du pays pour l'orthopédie.

Le mode de recrutement varie selon les groupes (Figure 2). Les médecins et les kinésithérapeutes jouent un rôle majeur dans le recrutement des bénéficiaires des groupes sportifs en cardiologie et obésité. Les associations en neurologie recrutent principalement elles-mêmes. Le milieu médical et les associations recrutent similairement en oncologie. Enfin, la famille et les amis des bénéficiaires sont les principaux acteurs du recrutement en orthopédie. Quels que soient les groupes, les recrutements dépendent actuellement de l'idéalisme de quelques acteurs clés (par ex. : médecins, kinésithérapeutes, responsables d'association, etc.).

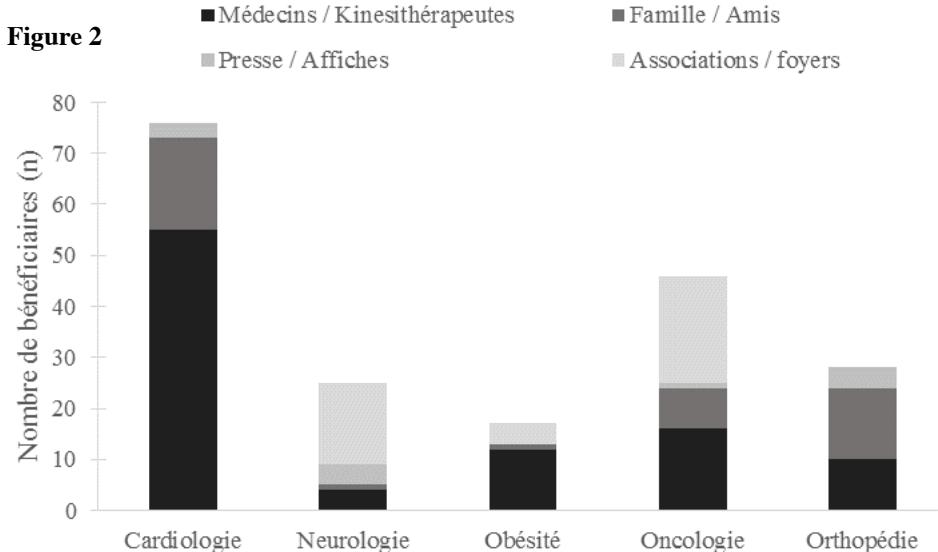


Figure 2. Mode de recrutement des bénéficiaires. Les bénéficiaires peuvent être recrutés par les médecins / les kinésithérapeutes (gris foncé), par la famille / les amis (gris anthracite), par la presse / les affiches (gris perle) ou par les associations / les foyers (gris clair).

Selon les catégories, la pratique d'activités physiques diffère depuis l'intégration dans les groupes d'activités thérapeutiques (Figure 3). En cardiologie, 61 % des bénéficiaires ne pratiquaient pas d'activité physique avant leur problème de santé et 5 % des bénéficiaires ne pratiquent pas d'autres activités physiques en dehors de celles proposées par les groupes d'activités physiques thérapeutiques. Les bénéficiaires obèses ne pratiquaient pas d'activités physiques dans le passé et pas d'autres d'activités physiques en dehors des cours proposés. En neurologie, oncologie et orthopédie, plus de 50 % des bénéficiaires pratiquaient des activités physiques dans le passé. Ils sont plus de 64 % à pratiquer d'autres activités physiques en dehors de celles proposées par les groupes d'activités physiques thérapeutiques.



Figure 3. Partie A : Taux de participation à des activités physiques avant la participation aux groupes d'activités physiques thérapeutiques (gris foncé : non-participation ; gris clair : participation). Partie B : Taux de participation à des activités physiques pratiquées actuellement en dehors des activités proposées par les groupes (gris foncé : non-participation ; gris clair : participation).

### ***Les bénéficiaires potentiels***

La majorité (62 %) des potentiels bénéficiaires du groupe sportif pour hanche et genou (le seul groupe interrogé à ce sujet) souhaitent participer à un groupe d'activités physiques thérapeutiques. La connaissance de l'existence de groupes d'activités physiques thérapeutiques est cependant faible à la fois chez ceux qui souhaiteraient y participer (76 %) et ceux qui ne le souhaiteraient pas (92 %). Les personnes qui ne souhaitaient pas participer sont légèrement plus âgées ( $66,8 \pm 6,0$  ans vs.  $63,5 \pm 9,9$  ans), sont majoritairement des hommes (54 % vs. 33 %), pratiquaient davantage d'activités physiques avant l'intervention chirurgicale (85 % vs. 62 %) et habitent plus loin ( $26 \pm 15$  km vs.  $20 \pm 12$  km). Les personnes qui ne souhaiteraient pas participer pensent que le lieu et les horaires des cours ne sont pas adaptés (61 % vs. 48 %).

## **Discussion**

Au Grand-Duché de Luxembourg, 11 groupes proposent des activités physiques thérapeutiques pour différents maladies chroniques (cardiologie, neurologie, obésité, oncologie, orthopédie). Ces groupes, dont la présence ne couvre pas suffisamment le territoire national, ne sont pas coordonnés entre eux et fonctionnent grâce à l'idéalisme de quelques acteurs. La participation aux groupes est très insuffisante. La capacité d'accueil est cependant limitée et les différents groupes ne pourraient pas accueillir plus de 10 nouveaux bénéficiaires par heure. Cette faible participation est la conséquence de la méconnaissance de l'existence des différents groupes d'activités physiques thérapeutiques.

### ***Une participation insuffisante***

Les premiers groupes d'activités physiques thérapeutiques ont été mis en place pour des patients atteints de problèmes cardiaques en 1984 en s'inspirant initialement du modèle allemand [8]. Ces groupes se sont développés tout au long de ces 30 dernières années et proposent l'offre la plus importante (3 sections et plus de 17 heures d'activités physiques par semaine). Toutefois, seulement 6 % des nouveaux bénéficiaires potentiels participent durablement aux groupes d'activités physiques thérapeutiques [8]. Les groupes sportifs pour cardiaques ont connu une forte expansion pendant les 15 premières années. Ces groupes sont dorénavant devenus un cercle de sportifs cardiaques très appliqués et disciplinés à long terme [8]. Ainsi, les nouveaux participants sont rares. Ce constat, fait pour les groupes sportifs pour cardiaques, peut s'appliquer aux autres groupes. En effet, la plupart des groupes sont récents (moins de 10 ans) et de nombreux bénéficiaires sont présents depuis la création des groupes. En 2014, entre 200 et 400 bénéficiaires participent aux différents groupes d'activités physiques thérapeutiques. Le nombre de bénéficiaires potentiels est certainement bien plus important. Or chaque groupe pourrait difficilement accueillir plus de 10

nouveaux bénéficiaires. La capacité d'accueil de ces structures pourrait ainsi être rapidement dépassée en cas d'afflux supplémentaire de nouveaux bénéficiaires. La participation au sein des structures existantes est actuellement insuffisante. Ce point est fondamental pour le développement des groupes. La participation dans les groupes sportifs pour cardiaques est probablement liée à la survie. Les bénéficiaires de ces groupes, qui n'étaient pas très actifs avant d'avoir leur incident cardiaque, pourraient voir un lien direct entre la pratique régulière d'activités physiques et leur survie. Il n'y a pas de lien direct pour la plupart des autres pathologies, le lien entre la survie et les activités physiques étant plutôt indirect. Il apparaît que les bénéficiaires en neurologie, oncologie et orthopédie étaient déjà actifs avant de leur pathologie. Il est probable qu'il soit difficile de sensibiliser les personnes atteintes de ces pathologies et qui sont chroniquement inactives.

### ***Une sensibilisation inefficace***

Par ailleurs, la faible participation est pour une part la conséquence d'une méconnaissance de l'existence des groupes à la fois des bénéficiaires potentiels et des personnes qui pourraient inciter les potentiels bénéficiaires à participer. Différents moyens sont possibles pour sensibiliser les populations. Actuellement, les recrutements sont faits principalement sur les conseils des professionnels de la santé (médecins, kinésithérapeutes) qui s'occupent des bénéficiaires pendant la phase aigüe de leur traitement. La prescription médicale d'activités physiques thérapeutiques, qui est déjà mise en place dans différents pays étrangers, serait un moyen pour sensibiliser les patients. Toutefois, les médecins de famille estiment ne pas être suffisamment compétents pour prescrire des activités physiques à leurs patients [19]. Actuellement, seuls les médecins de la clinique de l'obésité utilisent une sorte de prescription d'activités physiques au Grand-Duché de Luxembourg. Les autres moyens de sensibilisation sont également à renforcer. Les réseaux personnels (amis, famille, collègues de travail), les associations et les communications (orales et écrites) sont actuellement les principaux moyens de recrutement de certains groupes et devraient continuer à jouer un rôle. Le groupe d'activités physiques thérapeutiques peut apparaître comme un monde nouveau. Cette nouveauté et la crainte qui peut être liée à sa découverte peuvent être limitées par la dimension affective. Enfin, les communications orales ou écrites faites par des professionnels de la santé ou des sciences du sport (articles scientifiques, conférences dans les congrès scientifiques, conférences tous publics, conférences de presse), les médias (radio, télévision, presse écrite, Internet) et les affichages (affiches, flyers) sont également utilisés pour le recrutement des bénéficiaires.

### ***Une fidélisation à double tranchant***

La fidélisation des bénéficiaires est l'étape qui suit la sensibilisation. Actuellement, les groupes tentent de fidéliser leurs bénéficiaires. Cette fidélisation pourrait saturer la capacité d'accueil et c'est l'une des raisons pour laquelle certains groupes ne sensibilisent plus les bénéficiaires potentiels. Afin d'avoir une fidélisation efficace,

les expériences et les motivations personnelles sont à prendre en compte. De plus, la posologie du médicament « activités physiques » doit être respectée. Le dosage (volume et intensité), la fréquence d’administration (sessions par semaine), le type (aérobie, résistance) ainsi que les contre-indications de l’activité physique sont à prendre en compte afin d’optimiser son efficacité et d’éviter ses effets indésirables. Comme la plupart des médicaments, l’activité physique peut avoir non seulement des effets indésirables sur la maladie elle-même (par ex. incident cardiaque) mais aussi des lésions aigues (fracture, luxation, traumatisme crânien, rupture des ligaments croisés, entorse) ou des lésions chroniques (tendinites) qui peuvent empêcher l’activité physique et amorcer le développement de pathologies articulaires dégénératives quelques décennies plus tard. Le risque de blessures est réel et une blessure aurait un effet contre-productif pour la promotion de la santé. La recherche concernant les préventions des blessures sportives a permis d’élaborer des stratégies préventives. Cependant, ces stratégies ne sont pas systématiquement implémentées dans le cadre de la promotion de l’activité physique [10]. Par ailleurs, l’évaluation des performances est un moyen permettant une activité physique-sportive plus individualisée et donc plus efficace et en même temps la fidélisation des bénéficiaires.

### ***Des moyens limités***

L’expansion actuelle des groupes est limitée par le manque de moyens financiers et par la difficulté à trouver des locaux disponibles toute l’année. Pour la plupart des groupes, les structures sportives (piscine, gymnase, salle de musculation) sont prêtées par des établissements scolaires grâce à des initiatives personnelles. L’accès à ces structures n’est toutefois pas possible pendant les vacances scolaires et les horaires de disponibilité sont dépendants de l’utilisation des structures par les écoles. L’accessibilité et la gratuité des locaux permettent aux groupes de pouvoir se développer à coût réduit. Les coûts les plus importants sont liés aux ressources humaines (plus de 180 000 € par an). La somme des cotisations des bénéficiaires (plus de 30 000 € par an) est faible et ne permet pas de recouvrir les dépenses. Les aides ministérielles sont alors essentielles pour les groupes d’activités physiques thérapeutiques, en particulier les groupes sportifs pour cardiaques, pour payer les moniteurs, les médecins et les infirmières. Par ailleurs, certains groupes fonctionnent principalement grâce aux dons et à la participation financières des bénéficiaires eux-mêmes.

### ***Une formation hétérogène***

L’hétérogénéité des formations des moniteurs est importante. Les moniteurs qui ont suivi une formation spécifique sont rares, ces formations étant suivies en Allemagne. Cependant, la majorité des moniteurs ont suivi dans le cadre de leur formation initiale des cours concernant l’encadrement d’activités physiques thérapeutiques chez des patients atteints de certaines pathologies. Il n’existe toutefois pas de formation pour toutes les pathologies, en particulier pour les

pathologies neurologiques. Certains moniteurs se sont formés au contact des bénéficiaires qui connaissent les limites de leurs possibilités physiques/ physiologiques. Les feedbacks des bénéficiaires peuvent effectivement aider les moniteurs qui ne sont pas formés spécifiquement à construire les cours. Afin de pallier cette hétérogénéité, les moniteurs pourraient suivre des formations spécifiques continues évaluées (création d'une certification). Ces formations pourraient être créées au Grand-Duché de Luxembourg en collaboration avec des universités ou d'autres organismes. Les colloques médico-sportifs d'Eich, organisé par l'Académie Luxembourgeoise de Médecine, de Kinésithérapie et des Sciences du Sport, pourraient également servir de supports à ces formations.

## **Conclusion**

Plusieurs structures proposent des activités physiques thérapeutiques pour différentes maladies chroniques. En comparaison à d'autres pays, le Grand-Duché de Luxembourg est très en arrière en matière de soutien de ces initiatives par les pouvoirs publics et privés, alors qu'en termes économiques et de santé publique, tous les bénéfices à long terme sont indéniables. L'existence de ces structures est un point positif mais elle n'est néanmoins pas suffisante ni satisfaisante. Les groupes semblent être fragiles car leur avenir dépend exclusivement de l'idéalisme de quelques acteurs clés. En effet, la plupart des groupes dépendent de quelques personnes ressources qui gèrent la communication et le recrutement. Aussi, l'action de santé publique entreprise par les groupes devrait être pérennisée et renforcée par une meilleure structuration et une professionnalisation. L'augmentation du nombre de participants potentiels est l'objectif principal à atteindre par une meilleure connaissance du grand public et des milieux médicaux et paramédicaux. Cette augmentation pourrait être renforcée à l'aide de l'extension de l'offre à d'autres pathologies et à la prévention primaire pour certaines pathologies. La création d'une campagne publicitaire est nécessaire et devrait accompagner le renforcement de l'offre d'activités physiques thérapeutiques.

## **Remerciements**

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# **Hemifacial spasm caused by the cross-compression of the vertebral artery loop – a case-centered report of a stitched sling retraction technique**

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## **Abstract**

Hemifacial spasm (HFS) is one of the neurovascular compression syndromes caused by the compression of the facial nerve outgoing from the brainstem by an artery, a vein or both. The treatment of choice of this disorder is a microvascular decompression (MVD). As initially described, MVD is a technique based on the application of the small prostheses that are placed between a cranial nerve and an imposing vessel.

Neurovascular compression syndromes have relatively high rate of incidence. Therefore, many modifications of surgical technique have been described in order to minimize the risk of complications and increase the effectiveness and permanence of the vascular transposition as the success of the MVD most of all depends on the latter.

The authors of this paper describe one of the aforementioned modifications that provides a complete and permanent vascular transposition together with its advantages and limitations in the treatment of the hemifacial spasm. Moreover, many aspects of different technical approaches are widely discussed and a case-centered stitched sling retraction technique is presented.

## **Keywords:**

microvascular decompression, sling retraction technique, neurovascular compression syndromes

## **Introduction**

Hemifacial spasm (HFS) is one of the neurovascular compression syndromes caused by the compression of the facial nerve in the brainstem by an artery, a vein or both. It manifests as intermittent, painless, involuntary, spasmodic contractions of the muscles innervated by the facial nerve in one side of the face only. Moreover, it may be associated with trigeminal neuralgia, geniculate neuralgia or vestibular/cochlear nerve dysfunction [1]. Together with palatal myoclonus, HFS is the only involuntary movement disorder that persists during a sleep. It is important, however, to distinguish this dysfunction from facial myokimia (continuous facial spasm) and blepharospasm (bilateral spasmodic closure of the orbicularis oculi) as the treatment of the aforementioned diseases is completely different [1].

HFS is usually caused by compression of the facial nerve at its root exit zone (Obersteiner - Redlich zone). It is the point where central myelin (from oligodendroglial cells) changes to peripheral myelin (from Schwann cells). According to Janetta et al. the conflict is caused by the cross-compression of an artery loop that has imposed upon the nerve as a result of vascular elongation secondary to the aging process [2]. The nerve might also be compressed by the vein or by both artery and vein.

Neurovascular compression syndromes have relatively high rate of incidence [3]. Therefore, many modifications of the microvascular decompression (MVD) technique in order to transpose the imposing vessel and relief a patient of the symptoms have been described [2,4,5].

The success of the MVD depends, most of all, on the permanent and complete transposition of the offending vessel. The authors of this paper describe one of the aforementioned modifications that provides the latter together with its advantages and limitations in the treatment of the hemifacial spasm. Moreover, many aspects of different technical approaches are widely discussed and a case-centered stitched sling retraction technique is presented.

## **Case Report**

This paper is based on the case of our patient who underwent a MVD in our Department. She was a 60-year old woman without any particular past medical history, suffering from a right sided hemifacial spasm resistant to conservative treatment. The latter included carbamazepine up to 600mg/day. The patient underwent a thorough and advanced preoperative diagnostics in order to exclude non-vascular etiology and any other eventual pathologies important for a surgeon. MRI suggested the presence of vascular compression on the right facial nerve by the large trunk of vertebral artery [fig. 1].

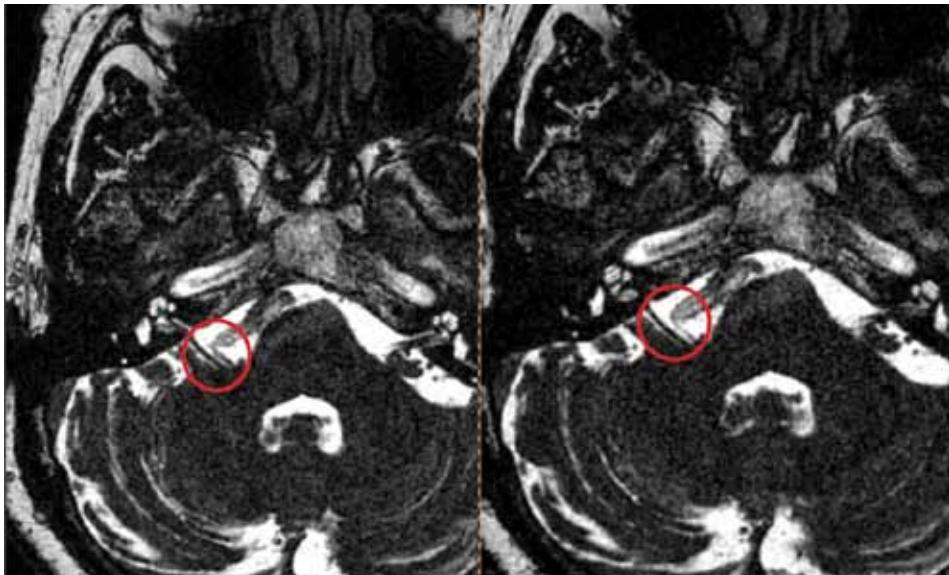


Fig. 1: MRI using FISP MRA sequence revealed a neurovascular conflict caused by the cross-passing loop of the right VA imposing the right facial nerve

## 1. Preoperative management

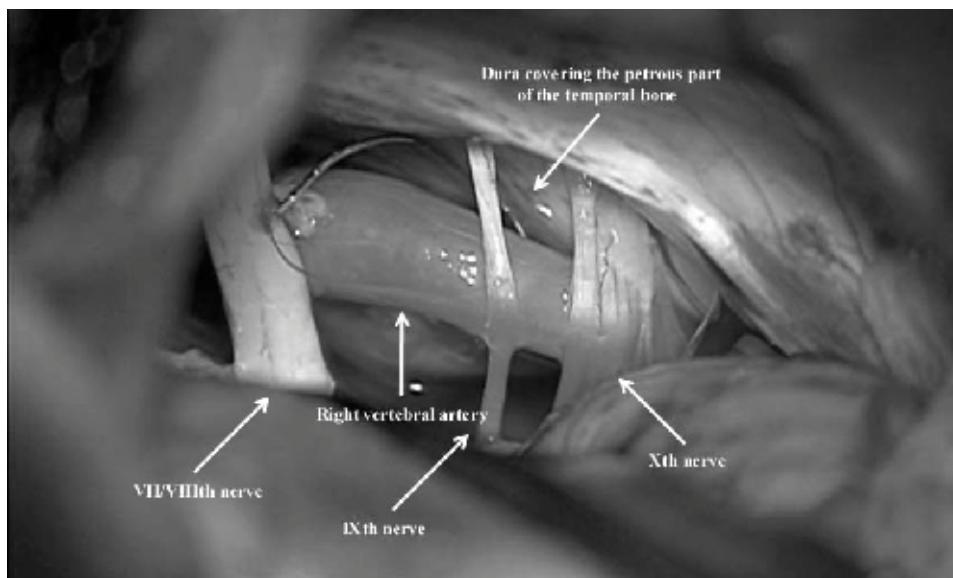
Specific Magnetic Resonance Imaging (MRI) techniques are necessary to estimate the anatomic proportions that provide additional preoperative details important during MVD procedures [fig. 1]. Moreover, it enables a surgeon to exclude any non-vascular cause of the hemifacial spasm and to explore and identify potential structures that may influence the surgical approach.

Among the MRI sequences available, a Constructive Interference in the Steady State Magnetic Resonance (CISS MR) combined with Direct Volume Rendering (DVR) and 3-Dimensional Fast Inflow with Steady State Precision MR Angiography (FISP MRA) have been the most discussed in the literature [6,7,8]. Both methods proved to be helpful in decision-making for the most optimal microneurosurgical procedure individualized for each patient providing, in addition, superior safety and improving the surgical outcome [9].

## 2. Operative technique

The patient was placed in the lateral decubitus position with the neck slightly flexed and rotated so that the retromastoid area on the affected side is the highest point in the surgical field. In order to prove adequate decompression we used intraoperative monitoring of the facial nerve Abnormal Motor Responses (AMR) (though some authors deny their predictive value) and Brainstem Auditory Evoked Response (BAER) monitoring to diminish the risk of auditory injury.

A small retromastoid craniectomy was made, with particular care to expose the sigmoid sinus, so that when the dura is opened and laterally suspended with tack-up sutures there is the most direct possible exposure of the lateral pontine and medullary cisterns, minimizing the subsequent need for cerebellar retraction. After introducing of the operating microscope, the lateral cisterns were fenestrated to remove the cerebrospinal fluid and relax the cerebellum. A single self-retaining retractor was then positioned with its distal ear immediately above the flocculonodular lobe to permit extensive arachnoid dissection in the cerebellopontine angle (CPA). The arachnoid around the cranial nerves VII-VIII complex and IX-X-XI was then sharply divided, followed by dissection of the arachnoid in the posterior aspect of the CPA, near the flocculonodular lobe. The retractor was then advanced further until its tip lied adjacent to where the choroid plexus extends laterally from the fourth ventricle. This generous and sharp arachnoid dissection is thought to be particularly important for enhancing exposure of the root exit zone, aiding brain relaxation and minimizing traction on the cranial nerves [7,10]. With particular care to avoid any harm of smaller vessels passing nearby and perforating the brainstem as well as the adjacent cranial nerves, the imposing arterial loop was firstly dissected from arachnoid and transposed. Due to its high resiliency it consequently returned to initial position and compressed the facial nerve. Therefore we had to permanently transpose the loop of right vertebral artery. We fixed it by means of suturing the artery trunk with single 5-0 non-resorbable suture against the dura covering the petrous part of the temporal bone [fig. 2 and 3]. The facial nerve was completely and permanently separated.



*Fig. 2: Intra-operative view from the surgical microscope demonstrating a stitching procedure prior to retraction of the imposing artery.*



Fig. 3: Intra-operative view of the surgical microscope after the retraction and complete transposition of the impinging artery.

The abnormal motor responses completely resolved immediately after decompression as observed in electrophysiology monitoring during the microsurgical procedure.

In presented case [fig. 2-3] we have obtained a complete postoperative resolution of clinical symptoms. No intraoperative or postoperative complications occurred following the surgery. The latter include hearing loss, aseptic meningitis or CSF leak [11,12,13,14]. After 7 days the patient was discharged presenting no residual symptoms.

## **Discussion**

Microvascular decompression, as initially described by Jannetta et al., is a surgical technique based on the application of the small prostheses that are placed between a cranial nerve and an imposing vessel [4,15]. The most commonly used material is a Teflon felt. Compared with other available materials such as Dacron sponge, Ivalon Sponge, cotton, periosteum, muscle or fascia it is well tolerated, not resorbed and has a lower complication rate. In most cases its application has a positive outcome. There is, however, a certain rate of recurrence varying between 6% and 38% due to granuloma formation around the implants following an adhesive inflammation and arachnoiditis [12,16,17,18,19,20,21,22,23,24]. Moreover, if the second intervention is required there is a high risk of nerve injury as a dissection of the prosthesis-nerve complex becomes more difficult and more dangerous [16,25,26]. However, complications such as arachnoiditis or granulomas occur relatively rarely and there is no control prevalence data provided in this issue. On the other hand, nevertheless, certain measures have been taken in order to modify the materials and techniques used in the MVD and eventually improve the outcome of the procedure. Such a material – a dural substitute made of expanded polytetrafluoroethylene, the Gore-Tex EPTFE patch and its application in the MVD has been recently described by Oiwa et al. [5].

According to the results delivered by Oiwa et al., the sheets of dural Gore-Tex substitute are sufficiently elastic to absorb the arterial compression. However, it is rather necessary to use the large patches in order to obtain a satisfactory decompression. Small sheets may be dislocated by the arterial pulsation or not be able to absorb enough compression. Moreover, dural substitutes may cause vasospasm or thrombosis of the arteries as it was described in the literature [5]. Therefore, further studies and technical improvements must be carried to reduce the occurrence of such complications.

In contrast, other methods should also be considered if the compression is caused by a large vessel such as an elongated vertebral artery. The transposition of the imposing vessel using a stitched sling retraction technique may be useful in such cases as large vessels are taken away from an offended nerve permanently and completely [22,27]. There is, however, some rate of possible risk related to this procedure as an offending artery may be supplying the brainstem through the short perforators [5]. These perforators may be easily and extensively stretched and cause severe consequences. Similar problem occurs when Posterior Inferior Cerebellar Artery (PICA) and its branches compress the root entry zone of the facial nerve behind the choroid plexus of the lateral recess of Luschka's foramen. In such a case, a cerebellar hemisphere might sometimes be retracted more excessively. As a result, facial nerve deficit may occur. It is usually caused by an excessive stretching of the nerve or its swelling following the cerebellar retraction [5]. This complication may be avoided by an extensive dissection of

the arachnoid around the imposed cranial nerve. Moreover, VIIIth cranial nerve may also be damaged if the cerebellar flocculus is excessively retracted medially [5]. Therefore, a constant intra-operative Brainstem Auditory Evoked Response monitoring is essential in order to minimize the risk of hearing loss.

In contrast, MVD using a dural substitute or other materials available for the procedure is easier compared with the stitched sling retraction technique. It is also not harmful to the cranial nerve but fails in case of large imposing vessels.

## **Conclusions:**

Even in experienced hands, transient or permanent deficit of the imposed cranial nerve still remains common despite intraoperative neurophysiological monitoring nor thorough consideration of technical factors. If the stitched sling retraction technique is to be performed safely and successfully, a stitch must be placed in such a way that the imposing vessel is appropriately retracted in the intended direction. Moreover, an appropriate surgical approach must be chosen in order to obtain a sufficient operative exposure around the compressed nerve so that the stitching procedure is performed as safely as possible.

Among all the techniques discussed in this paper, a stitched sling retraction technique provides permanent and complete transposition of the offending vessel. Regardless the technique, however, there is still a lot of possible complications related to the MVD. Therefore, it is essential to adjust the choice of an adequate procedure to the location of the neurovascular compression, intraoperative anatomic findings and – most of all – the surgeon's experience.

The presented case is an example of our philosophy regarding management of neurovascular compression syndromes. In our opinion the best decompression is relocation of the offending vessel so as to obtain permanent lack of contact between the nerve and the vessel. It is especially important in case of large, elongated arterial trunks which have high degree of resiliency and continuously restore the compression. Large arteries produce strong pulsating pressure on the nerve even if one is separated by the patch of absorbing material, therefore, we recommend described technique in such a situation.

We suggest using this technique or its modifications in every case of compression syndrome if the anatomical conditions allow for the vessel relocation. In our opinion retraction technique advantages are definite nerve decompression and no need for using of artificial material what facilitates second look surgery.

Despite its advantages this is quite difficult technique which should be considered by more experienced neurosurgeons.

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# Rorschach Missing Responses – “Est-ce plus que rien?”

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## Abstract

The Rorschach has been demonstrated as a suitable tool for investigating otherwise hidden psychological aspects of sex offenders: sex-related responses are more common. The present paper looks at the established tendency of some clients to minimise their overall Rorschach responding, the linking of this response restraint to particular Rorschach profiles, and the sparse but consistent literature which casts doubt on the proposition that Examiner enthusiasm will cause the minimising client to provide more responses which divulge additional information. In the case of sex offenders, with so much to hide, it is proposed that there may be extensive filtering of responses even among those giving more than “normal” sex-related responses. “What the client did not say”, and the corresponding “missing” Rorschach responses in the case of sex offenders is discussed in the light of an individual case: (a sex offender with undue interest in young boys’ penii) where “sex-like” images were specifically targeted, but never named as such. The exciting prospect of inferring what the client could have said and thus generating the content of missing Responses, whether or not response filtering produced numerical minimisation, must be balanced against the risk of naked men and women (and their genitalia) representing nothing more than an artefact of the clinician’s own making – “ce qui n’est pas le cas”.

**Keywords:** Rorschach; expressive constraint; sex offenders; missing responses; repression.

## Introduction

For nearly a century, the 10 Rorschach inkblot plates have been employed by counsellors of every shade: it is a test which among other things is understood to reflect thoughts and ideas and attitudes that the client may not otherwise openly express. The need to see through the denials and evasiveness of sex offenders raises the prospect of the inkblot test providing otherwise unavailable psychometric substance. The present paper discusses the question of what is “missing” in what a client says, and does not say, when presented with a Rorschach card – and leads to a case study of sex offender and the interpretation of the responses that were never offered.

The Rorschach-enabled glimpse into the veiled domain of the client’s inner mental world may be vectored by overt language and descriptions of images stimulated by the cards: for example the response *it is two ladies arguing over possession of a baby* is by measure of word matching, only a short orthological step away from *two ladies looking at a baby*, however the Exnerian scoring system (which has around 100 variables) would distinguish between these two responses with, as a start, differential scores on “Aggression”. Quite different would be the contributions to Exner variables triggered by a description of the same plate as a ceramic vase, *with engravings of a butterfly flapping its wings on the side, and these two parts being the handles*. Among the first order variables lost in the pot would be those relating to “human movement” and interaction or “cooperation”, and the scorer would have to decide if *an engraving . . . flapping its wings* is an inanimate image or should receive marks for animal movement. This example barely touches upon the complexity of Rorschach/Exner scoring, but illustrates the fact that aggregate scores are affected not only by the content of the images perceived by the client, but also by the imagined actions and interactions.

Given the Rorschach power to plumb the client’s masked mental world, given the further fact that estimates of around one million administrations of Rorschach occur every year in the United States alone, and in part because of the inkblot’s ability to cross language barriers (leading to a strong European endorsement of the test), and finally given the elusive non-disclosing nature of sex offenders, it would be reasonable to expect an emphatic strand of interpretative writings which focus upon offending sexual behaviour. However this anticipated mountain of professional musing does not exist and in its place we find a mere molehill of Rorschachian study: a database search of the literature scored 14,886 hits for “Rorschach”; considering that at least half the population (men) think about sex every seven seconds, there is a relatively modest hundred year aggregate for {Rorschach + sex} with 872 references; but the domain where one could imagine the Rorschach might make a real contribution in uncovering or elaborating upon the inner workings of sexual fiends {Rorschach + “sex offender”} has achieved an average of only one paper every three years (total 35 hits). No matter how the

search terms are tweaked, the studies on sexual offenders and Rorschach are, in the main, “missing”.

## Rorschach and “missing” responses.

To evoke the descriptor “missing” is not without precedent in the Rorschach context: a considerable wealth of literature and expert opinion is devoted to the study of “missing” responses. The population mean number of responses is around 22 (1) and protocols are regarded as “short” (meaning that some potential client interpretations are “missing”) when that total drops below fourteen (1). The differential diagnostic interpretation of a short protocol is the choice between, on the one hand, “expressive constraint” (a relatively enduring quality of the client who has a tendency to not disclose thoughts and feelings), or on the other hand it may be that the limited number of visions reported upon is an indication that the responder did not have a sense of familiarity or ease of communication with that particular Examiner. Exner (1) devotes two pages to the issue of “Brief rotocols” and, in over-view, the remedy suggested is advising the client that this was not sufficient, and then gently goading the recalcitrant into providing more. However there is no Exnerian interpretative strategy to ascertain if the additional responses achieved from enthusiastic prompting would be truly representative of the “missing”, responses withheld by the client. Logically there are two classes of additional responses which may be achieved by prompting: (a) the extra responses will be representative of those which were not originally forthcoming and thus may now add not only to the volume of the protocol, but also to the richness of the interpretative process or (b) the extra responses are benign variations on the imagery, the themes, or at least the *style* which the client had felt comfortable in offering on the first pass.

Accepting that Examiner-client interactions can result in shorter protocol leads to the generally un-addressed question as to the content of the missing responses: there is the dark alternative that there conceptually exists a class of responses (those deemed to be missing ) that were never going to be offered, and possibly never will be offered in that particular Examiner/Responder situation despite the additional encouragement. This latter interpretation, that for a given situation some potential responses are never going to emerge, is compatible with the proposition that *Rorschach scores must be understood as complex products of multiple psychological operations and may correspond to different subjective experiences in various contexts* (2). Further, the folly of imagining that “encouragement” will uncover the with-held responses (as opposed to producing “more of the same”) has been recently demonstrated, using a modified technique which did indeed produce “significantly more responses while producing **minimal differences** on other examined variables. This alternative administration method was able to restrain variation in R without changing overall scoring on the Rorschach,

*which subsequently increased the [perceived] stability and validity of various variables*". (3). The "stability" referred to is analogous to obtaining "more of the same", however the question of "validity" in the sense of uncovering the workings of the client's mind is unresolved by merely eliciting more (similar) responses. The validity of any psychological test (Rorschach included) is anchored by the expectation that the results obtained are a reflection of the client, not of the phenomenology of the test situation. The concern about the nature of the "information which is not there" in the case of **pseudo expressive constraint**, is already discussed (4) as an example of an interaction with (or really a lack of interaction with) the Examiner as opposed to the alternative of ascribing responsibility to the examinee with a "blame the victim" diagnosis of "expressive constraint" (5). The prospect that the "missing" responses could reveal an otherwise masked view of the client is illustrated in a study of repeated inkblot administrations: it was confidently reported that the Rorschach protocols reflected the **restrictive personality** type (6) from the responses on the 1st and 3rd administrations, while the second test displayed the "opposing personality type".

The present musing shifts focus beyond the volume of responses, beyond the intermittent or enduring inferred personality quality of "constraint": of far greater interest, whatever the cause of a short protocol, and arguably of equal importance in the event of an acceptable volume of output is the question "what would the client have said if s/he had been yet more forthcoming?" Among the "withheld" responses in any protocol might be imagery which touches upon topics perceived by the responder as socially sensitive - and most relevant to the present forum these repressed blot interpretations may well reveal aspects of, or dominance of, sexual interests: *Rorschach sensitivity to minimization is important in forensic evaluations of sex offenders* (Grossman et al 2002).

Developing from the consideration of "missing" Rorschach responses:

- there is some, but surprisingly minimal, study on the use of Rorschach with sex offenders, thus the domain is seen as "valid but sparse";
- there is past and relatively recent (7) agreement that sex offenders may not be forthcoming in their Rorschach imagery;
- an overriding view of "withholding" responses in Rorschach literature focusses upon an assumed client personality style described by terms such as "constraint", although the same extensive literature base concurs that phenomenology is a key variable in restricted response sets.

As if in pre-emptive summary, there exists historically-offered advice that Examiners should be on the alert for "signs" of what the client is not disclosing: *The psychologist needs to increase his sensitivity to the presence of repression . . . repression may be identified through sensing that something is missing in the response* (8)

Taking these general points together, the case study detailed below is provided as an example of the need to consider the question as to whether “something is missing in the response”. The mention of a sexual image is found in only about 8% of Exner’s normative data, whereas among a group of sex offenders, almost half of the Rorschach protocols had *at least one response with sexual content* (7).

Two alternative conclusions may be drawn from Grossman et al –

- a. building on 500+% increase in risk of sex offenders seeing a sexual image at least once it is reasonable to ask, given this behavioural sign that they are indeed “interested in sexual images”, if this elevated interest is really so blunted as to allow them to “see” a sexual image in only one of the ten plates, or are they repressing (either consciously or otherwise) multiple other potential sexual image sightings. The interpretation of repression makes sense of the Grossman data (7) and leaves open the possibilities that (i) although reporting some scant few sexual images they really could have gone much further, and (ii) the other half of the Grossman sex offenders were also “seeing” but not reporting multiple sexual images in the plates.
- b. The unconvincing alternative view is to accept that the data is exactly what it seems to be, and for sexual offenders, despite their perverse “real world” behaviours, sightings of sexual images in the Rorschach plates are indeed rare. Thus, although for nearly half of sex offenders the administration of Rorschach culminates in a single erotic moment, nonetheless for such folk the modal number of sexual responses is zero. (7)

Responding to the suggestion that “repression” is in play, the orthodox Rorschach (really Exner) riposte involves resort to higher order pseudo mathematical functions where conceptual weight is given to specific observable behaviours (like the mention of “colour”, for example, this, in its absence, being one of the markers of “constraint” (6)), and then these individual response styles are built into a complex and essentially opaque gestalt which is neatly boxed up and labelled “constraint”. It is only with significant disquiet that his notion of “constraint” can be attributed to the client (either as a labile responding style or as a personality quality): constraint has already been exposed as a quality which may not be representative of the client but draws (at least a proportion of) its contribution from the Examiner (4).

For sex offenders who likely (certainly?) have issues to hide, the first choice of orthodox Rorschach interpretation (a higher order, pseudo-mathematical “quality” – *restraint*) may be no more than an artefact: “Everybody knows that the naked man and woman are just a shining artefact” (9). It may then be more appropriate to return to the roots of psychology: *the study of behaviour*. The following case study shows how observation and interpretation of **behaviour** rather than response content, and certainly rather than complex calculation, firstly revealed at least

something important about a Rorschach sex offender client, and secondly how the information thus obtained was clinically useful.

## **Case Study: Responses impoverished by Penis Withdrawal**

An illustration of what is not there is the case which could be called *the penis man*. He had been caught fondling the penis of each of several young boys. He had been sufficiently diligent, sufficiently prepared in advance, and sufficiently entranced by the topic of the penis that he had located on his mobile phone websites detailing the size and shape and function of the male organ from childhood to maturity and he was using these images to assist the boys in their journey of mutual exploration. Yes! This man was certainly interested in visual representations, as well as the physical manifestation, of the penis.

Over a period of several clinical sessions, this man never had a convincing explanation of his behaviour, and indeed seemed somewhat mystified, and also ashamed, by what he had done. The way this case was developing, his Rorschach responses would surely be interesting, very interesting indeed.

## **Results**

The results of Rorschach, at least those deemed relevant to the present paper, are found in Table 1: these being total responses, an indication of “normalness” of imagery (Populars), and the number of sexual images mentioned. This client did not perceive any indication of any genitalia in the plates, and gave remarkably benign and “normal” responses: his score on “Populars” was 6. However when the responses, and the man’s behaviour during the response phase, are held against the template of “what could be missing here?”, then the number of potential sexual responses totals 7, as shown in Table 2.

**Table 1**  
**Summary of Rorschach Scores for Sex Offender**

Score	Client total	Non-patient mean, sd (Exner, 2003)	Response normal (mean +/- sd)
Total Responses:	21	22.9, 5.51	normal
Populars	6	6.30, 1.58	normal
Sexual responses	0	0.18, [0.49]	normal

**Table 2**  
**Rorschach Potential Sexual Images**

<b>Plate, area</b>	<b>Response and Inquiry where relevant</b>	<b>sexual image (rating)</b>
II, D2	“red bits”, “red blobs” ?? “no idea what they are ?? “cb legs with shoes or two guitars”	D2 Penis (-)
II, Dd25	“this bit is a tail (Dd25)” but touching and physically drawing attention to area Dd24 as he speaks	Dd24 Vagina (o)
V, D9	“a bat, (W) because it has these little legs” (D9)	D9 Vagina (-)
VI, D6	“a violin. (W) This is where you tune it up (D6)”	D6 Penis (o)
VII, D5	“two rabbits or dogs sitting on a log. (W) You can see these ears (D5)”	D5, Penis (-)
IX, W	V “plums growing on a tree” (W)	W Vagina (-)
IX, D6	V indicating the central part of the red area while saying “these are the plums”	D6, Vagina (-)
<b>sexual total</b>	<b>Actual total = 0</b>	<b>Potential total = 7</b>

## Discussion

The extract of this client's protocol points towards “normal” levels of responding in total, in content and in absence of sexual images. However adding his behaviour (actually touching or strongly verbally drawing attention to specific components of otherwise “whole” images) the candidate conclusion here is that this was an example of either deliberate, or (more or less) subconscious withdrawal of any penis from the images he was prepared to mention. Harking back to the accusation already invoked by the expressive constraint issue *est-ce que c'est vous-même dans la glace?* (4), the disappointed Examiner in this case, faced with a void of male genitalia responses, deservedly stimulated the query “on which side of the desk lies the penis obsession?”.

*On which side of the desk? . . .* in an entirely different case, a client had been the subject of one of those “forensic psychological” reports which lurches between describing any and all aspects of the subject's personal history, however irrelevant to the present matter, and pseudo verbatim description of the interview. This client had an IQ around 70, with particularly poor verbal skills, but this did not prevent the interviewer recording that he posed the question “so you have a morbid fascination with the hairless vagina, don't you?” to which the client (so it was reported) said “yes”. Then in his Opinion, this Expert Witness asserted: *this man has a morbid fascination . . . etc*. One could not help but wonder on which side of the desk this lay *morbid fascination*. And, far removed from repressed sexual

connotations, around the 1950s optical telescopes had achieved sufficiently high resolution as to almost make out long straight lines on the planet Mars, so nearly unequivocal that these “canals” were certainly accepted, by some, as signs of intelligent life on that planet: «Lowell always said the regularity of the canals [very nearly, but not quite visible by optical telescope] was an unmistakable sign that they were of intelligent origin. This is certainly true. The only unresolved question was which side of the telescope the intelligence was on.» (10)

Noting that Exner’s normative score for Sx responses is around zero or 1, then every client who does not see sexual images in the cards cannot be judged as showing denial of sexual matters. The interpretation of denial needed to be finer than merely noting what is not there, and bearing in mind that this was not a case of trying to find out if he was an offender (that was already admitted), but rather the clinical process was part of an attempt to understand what was wrong and find a route to fix this. Thus the final pronouncement might be best arrived at as an honest collaboration.

Review of the detailed protocol disclosed that the client pointed out several (six in fact) examples of areas which have been recognised as “like a penis” (1). In one particular card which had been identified as “like a violin” he had specifically jabbed with his finger saying “and this section here, this is where you would tighten the strings”, repeatedly touching the area which has been described as phallic - however he did not say the P word.

Relevant to the act of actually touching the “penis like” area of the blot, long since emphatic interpretative comment has been made about the Rorschach test and human movement:

*Rorschach himself strongly insisted on the distinction between the true experience of movement and the spurious, merely verbal, talk about movement.* (11) and so, drawing from Rorschach himself, the present case study takes the importance of “movement” out of the verbal response phase and into the real world.

After the Rorschach, our discussion turned to the really quite obvious the penis-like quality of the particularly selected areas of the Rorschach plates: we jointly discovered that he had indeed singled out remarkably penis-like areas but had given a non-penile response. Could this mean that the “true” image in his mind was displayed in the behaviour but not the words? And what did this mean, to him? This line of conversation led to his previously uncovered sense of enduring shame relating to an experience about 10 years ago: a six month long explorative relationship with another male, his only “other” sexual activity ever, when he and the other male were both about 20 years old. He had not only never mentioned this sexual activity to anybody, ever, he also was emphatic that he “tries very hard never to think about” that period and most certainly attempts to never entertain images of the activities involved.

## Conclusion

There is a century-long evolution of Rorschach, with the continued and undenied thread that this test may help the clinician to look beyond what a client is prepared to divulge openly. There is an equally continuous discussion about clients who are not saying as much (in quantity or in quality) as they could. The case study here shows the clinical benefit of an Examiner/interpretative approach which derives from the perspective that the test is a tool which can help the Examiner, rather than regarding the Examiner as a tool of the test.

In overview this case demonstrates:

- that the Examiner-perceived missing penis responses did in fact relate to what the client brought to the consultation, and was not tainted by the Examiner's predilections
- that the broader issue of short protocols and "missing responses" is in line with earlier literature, proving to be far more complex than can be solved by demanding "more volume" from the client. Given that clients across a wide range of imaginative and intellectual abilities can comfortably return around 20 separable responses, the occurrence of short protocols must be regarded as evidence not so much of "lack of effort", not so much as "expressive constraint", but as a potential sign that the client is either consciously or subconsciously with-holding certain answers which would likely (inevitably?) be clinically meaningful. Unfortunately these additional data are not necessarily accessed simply by asking for more.

Although it is suggested here that the interpreter ponder the question "despite what the client is saying, or not saying, what might they be thinking?", there is no straightforward process for solving that particular puzzle. Possibly focussing solely upon sexual offenders and sexual imagery which could be, but in fact is rarely, mentioned in Rorschach responses, it might be possible to concoct a score of "potential sexual images mentioned by the client, but not acknowledged as such", starting for example with the neck of the violin (D6 in plate VI). Although the interpretation of sexual imagery where none was mentioned in the present case was based upon behaviour so stark as to mirror the guilt and repression-driven self-revealing action in Poe's *Tell Tale Heart* (12), it remains the fate of the clinicians who guess at what the client is not saying that this opens wide the door for criticism once meted out to other imaginative observers of information which was not quite visible, not in fact there at all. Like the astronomers of a previous century, or is it unlike them altogether, opinions based upon "what is it that is not there" should be cloaked with caution: *peut-être, il n'y a pas.*

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# **The Prediction of Epidemics through Mathematical Modeling**

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## **Abstract:**

Mathematical models may be resorted to in an endeavor to predict the development of epidemics. The SIR model is one of the applications. Still too approximate, the use of statistics awaits more data in order to come closer to reality.

**Keywords:** epidemics, statistics, prediction.

## **Introduction**

The writings of David Quammen, e.g. in Spillover, on the mathematical aspects of epidemics, are an incitement to examine further the spread of infectious diseases. I decided to explore the mathematical possibilities underlying this topic and how they may contribute to staving off major outbreaks.

## **Purpose**

The aim of this exploration is to investigate the relationship between the statistics gathered for certain infections and the possibility to predict future outbursts of these diseases, using mathematical models. I will focus on infectious diseases that rely mostly on individual-to-individual contact to spread. I want to explore the different aspects that surround this subject, and how it can affect communities and our global world as a whole. Epidemics do occur all over the world and often authorities are not sufficiently prepared to prevent them, with resulting damage to communities and sometimes global impacts. This has become an even more important matter in today's world, where the spread of a disease is accelerated by modern technology and the quarantining of a certain area is a near impossibility. The accurate prediction of epidemics would be a blessing for the global community.

## **Method and Results**

Infectious diseases are spread over the interconnecting networks of humans and/or animals; basically, if one contagious individual comes in contact with another, the latter is in danger of being infected as well. Obviously, some people do not become infected at all for reasons unknown to scientists. Theories that are developed remain tainted by uncertainties which must be taken into account.

It is important to briefly mention the “butterfly effect”, since infectious diseases are affected by many factors and can be handled in many different ways. The butterfly effect would also explain the reason for quarantines, because they theoretically stop the spread of infection. Butterfly effect: if somebody were to modify one of his or her actions, the outcome would change completely. For a long time it was thought that small actions bear small effects, but now we know that a small action may exert a huge effect on the final outcome. For example, if a person becomes infected by zoonotic disease from close contact with an animal, different scenarios can occur. If the infected person were to be admitted to a hospital, a domino effect could cause the staff as well as visitors and other

patients to catch the infection. If, however the infected person were prevented from coming into close contact with other humans, the disease would obviously not spread.

I am going to focus on Kermack and McKendrick's epidemic model published in 1927 in the Proceedings of the Royal Society of London Series A. The authors assume that the survivors of the infectious disease become immune (as for example in the case of measles), or die if stricken by a lethal infection. The population is a given; the births and deaths unrelated to infection are ignored. Kermack and McKendrick assume that all members start out with the same degree of susceptibility.

We have to differentiate between three types of individuals: the susceptible ( $S$ ), the infected ( $I$ ), and the removed ( $R$ ). A susceptible person has not yet been infected and is prone to infection. An infected person is currently infected and has the potential of passing the disease on to others through contact. A removed person has survived infection and is now immune to the disease, or has died and cannot infect others anymore. The SIR model explains that the individual transits through the stages accordingly:  $S \rightarrow I \rightarrow R$

This theory goes as follows: one or more infected individuals are placed into a community, the disease then spreads amongst the population through contact. Each member goes through the SIR model and in the end is removed from the pool of infectious members. The stage of the sickness has a strong effect on the likelihood of infecting others, as well as on the chance of recovery for a certain individual.

The general epidemic process is given by the SIR model. We know that:

Number of susceptible at time  $t$ :  $X_t$ ,

Number of infected at time  $t$ :  $Y_t$ ,

Number of removed at time  $t$ :  $Z_t$ ,

Rate of infection between individuals:  $\beta$

Rate of recovery of an individual:  $\gamma$

Number of people in population:  $N$

Expected length of infectious period:  $\frac{1}{\gamma}$

The SIR model is a continuous differential equation model which can be obtained with the simple cycle of infection explained in the above paragraph. We set up a probability model supposing that:

$$S_t = \frac{X_t}{N} : \text{percentage of susceptible at given time } t$$

$$I_t = \frac{Y_t}{N} : \text{percentage of infected at given time } t$$

$$R_t = \frac{Z_t}{N} : \text{percentage of removed at given time } t$$

An individual always has to be in one of the three above states.

The number of the population does not change and thus we can obtain the following:

$$X_t + Y_t + Z_t = N$$

$E$  stands for the expected value and we calculate the expected value at time  $t + 1$

Using the assumptions from above we can set up the following equation:

$$E(X_{t+1}) = X_t \times \left(1 - \frac{Y_t}{N} \times \beta\right)$$

The equation shows that susceptible individuals at time  $t$  remain at a susceptible state with a probability of  $\left(1 - \frac{Y_t}{N} \times \beta\right)$ ; this is because individuals will be moved out of the susceptible group into the infected group.

$$E(Y_{t+1}) = X_t \times \left(\frac{Y_t}{N} \times \beta\right) + (Y_t - \gamma \times Y_t)$$

This equation shows that  $X_t \times \left(\frac{Y_t}{N} \times \beta\right)$  susceptible individuals enter the infected state and that  $Y_t \times \gamma$  infected individuals leave the state of infection into the removed state.

$$E(Z_{t+1}) = Y_t \times \gamma + Z_t$$

Here we see that to the already removed individuals we add the ones that move from infected to removed at a rate of  $Y_t \times \gamma$ . This equation simply proves that the members that join the removed state remain removed.

We are able to rearrange the previous three equations into:

$$\begin{cases} E(X_{t+1}) - X_t = -\beta \times X_t \times \frac{Y_t}{N} \\ E(Y_{t+1}) - Y_t = \beta \times X_t \times \frac{Y_t}{N} - \gamma \times Y_t \\ E(Z_{t+1}) - Z_t = \gamma \times Y_t \end{cases}$$

By implying  $\Delta t$  we make a discrete time model moving by the difference of  $\Delta t$  that is smaller than 1 and within the range of all real numbers. Substituting  $\Delta t \beta$  instead of  $\beta$ , and  $\Delta t \gamma$  for  $\gamma$  we are able to create this step. We get the following new equations:

$$\begin{cases} X_{(t+\Delta t)} - X_t = -\Delta t \beta \times X_t \times \frac{Y_t}{N} \\ Y_{(t+\Delta t)} - Y_t = \Delta t \beta \times X_t \times \frac{Y_t}{N} - \Delta t \gamma \times Y_t \\ Z_{(t+\Delta t)} - Z_t = \Delta t \gamma \times Y_t \end{cases}$$

One problem we face though is that they are fixed at a 1 unit time interval; we must find their derivatives in order to find the solution, as it is proven that a geometric random variable turns into an exponential random variable when derived. Dividing all three equations by  $\Delta t$  as well as having the limit  $\Delta t \rightarrow 0$  gives us three differential equations of continuous time and state of the SIR model.

$$\begin{cases} \frac{dX_t}{dt} = -\beta \times X_t \times \frac{Y_t}{N} \\ \frac{dY_t}{dt} = \beta \times X_t \times \frac{Y_t}{N} - \gamma \times Y_t \\ \frac{dZ_t}{dt} = \gamma \times Y_t \end{cases}$$

We can now substitute in the variables  $S_t$ ,  $I_t$  and  $R_t$  from earlier on to simplify it:

$$\begin{cases} \frac{dS_t}{dt} = -\beta \times S_t \times I_t \\ \frac{dI_t}{dt} = \beta \times S_t \times I_t - \gamma \times I_t \\ \frac{dR_t}{dt} = \gamma \times I_t \end{cases}$$

## SIR Graphs

I used a special online predictor\* to make the SIR graphs. When plugging in the data for the epidemic, the calculator predicts the behavior of the population. The data is given through three graphs; each one represents one of the three categories as pointed out earlier (susceptible, infected, and removed). In order to create graphs displaying how the spread of a virus behaves, we must determine certain initial variables as well as the effect of the virus on its host. We need to be precise about the virus itself, and come up with its infection and recovery rates. Initial conditions regarding the population must be set up; as we deal with a non-dimensional constant, we express  $S, I, R$  in fractions of one, resulting in a total population equal to one. The time units I chose to use are days, but they could be any unit of time. The time during which this spread is measured also has to be determined in days. The units for beta and gamma are  $\frac{1}{\text{time}}$ , thus in this case  $\frac{1}{\text{days}}$ . One problem with this graph calculator is that there is no way to modify the y-axis, thus all three graphs end up having different unit intervals. Moreover, the axes are not well labeled, the x-axis stands for the time units and the y-axis represents the number of individuals from the population.

### Graph One

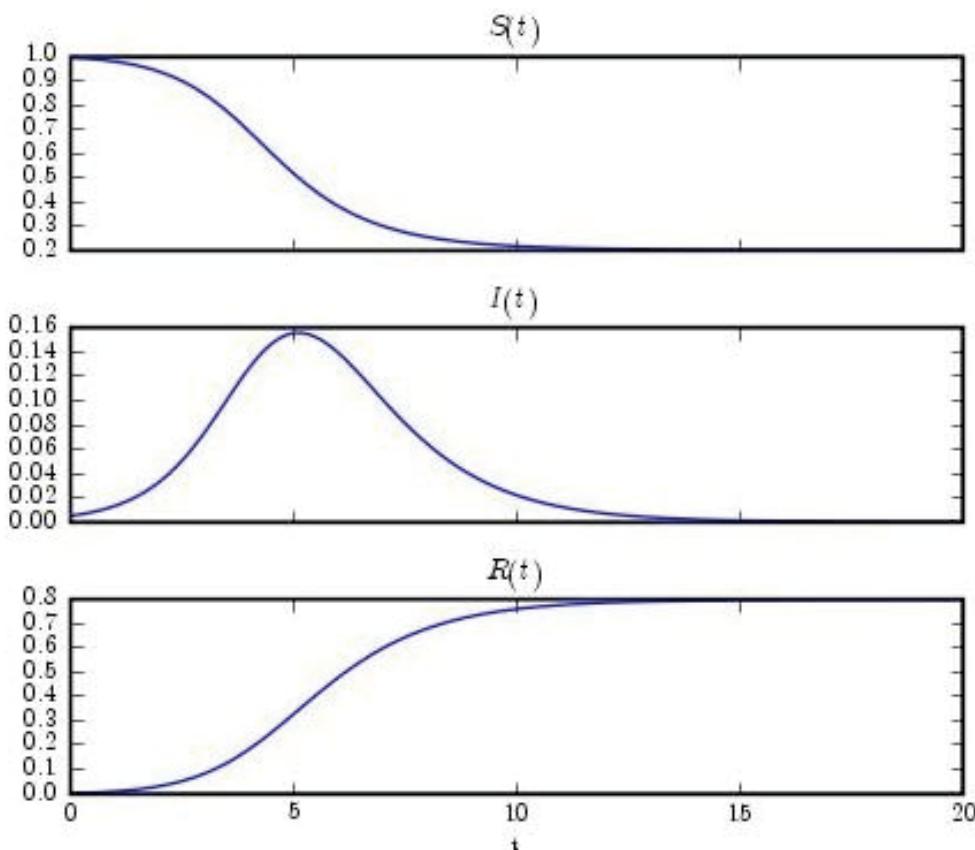
For the first graph (Graph One) I am using the variables set up automatically by the calculator; they give the “perfect” SIR graph representation, a pattern that is recurring for most cases. If we were to put together all three lines it would give us the representation seen in Graph Three. The parameters I start with are an infection that occurs within half a day, while the recovery occurs after a day. This is how I calculated the parameters for this graph:

$$\beta = \frac{1}{\text{days}} = \frac{1}{0.5} = 2.0$$

$$\gamma = \frac{1}{\text{days}} = \frac{1}{1} = 1.0$$

Parameters	Initial Conditions	Time (days)
$\beta = 2.0$ $\gamma = 1.0$	$S_0 = 0.995$ $I_0 = 0.005$ $R_0 = 0.0$	$t_{MAX} = 20.0$ $t_{MIN} = 0.0$

\* [http://www.warrenweckesser.net/solvers/menu\\_sir.html](http://www.warrenweckesser.net/solvers/menu_sir.html)



*-Graph One-*

Looking at the graph we can see that only 0.5% of the population starts out as infected, whilst the rest is susceptible. The maximum percentage of the population being infected at a certain time is 16% seen as the local maximum on the graph, which would be at approximately day five. This does not mean that only 16% of the population becomes infected overall, because individuals are constantly moving in and out of the groups, the recovered ones are subtracted and the newly infected ones are added. The epidemic lasts only around 15 days and overall 80% of the population becomes infected, then recovers, while 20% of the population is never affected and thus remains susceptible for the next breakout of this contagious disease.

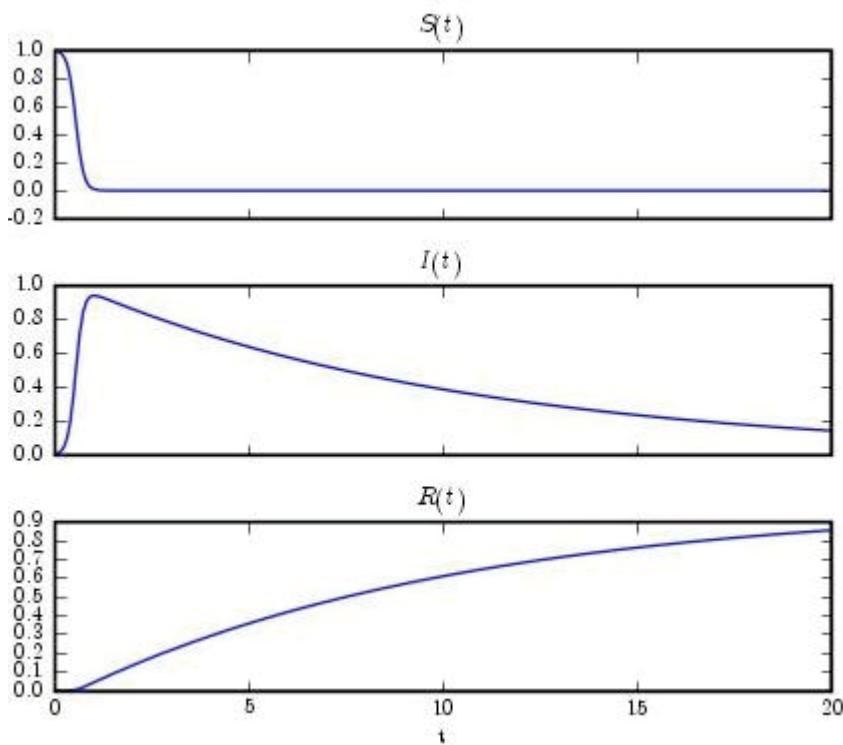
### Graph Two: Changing the recovery and infection rates

Here we are going to work with a very high infection rate and a very low recovery rate. I chose to consider an infection that occurs within a tenth of a day, while the time to recover is 10 days.

$$\beta = \frac{1}{\text{days}} = \frac{1}{0.1} = 10.0$$

$$\gamma = \frac{1}{\text{days}} = \frac{1}{10} = 0.1$$

Parameters	Initial Conditions	Time (days)
$\beta = 10.0$ $\gamma = 0.1$	$S_0 = 0.995$ $I_0 = 0.005$ $R_0 = 0.0$	$t_{MAX} = 20.0$ $t_{MIN} = 0.0$



-Graph Two-

The graphs show that the epidemic is far more widespread than in Graph One. Like previously, only 0.5% of the population is infected, but as these individuals take more time to move out of the infected state there is more time for them to infect others. Thus we end up with 0% of the population left in the susceptible state, which means that if there were to be another outbreak, none of the individuals present in this time period would be affected since they enjoy immunity. Because the recovery rate is so low, after 20 days not every member of the population has recovered yet. Thus we may conclude that the higher the difference between the infection rate and the recovery rate, with the infection rate bigger than the recovery rate, the more members of the population are affected and the longer the epidemic will last. This means that the number of individuals subtracted from the susceptible group is larger than the number of

individuals added to the removed group, in other words  $\frac{dS_t}{dt}$  is bigger

than  $\frac{dR_t}{dt}$ . A similar conclusion may be drawn in the opposite direction, when

the infection rate is very low and the recovery rate high; a very small percentage of the population will then be affected since the epidemic dies out fast because all the infected individuals recover in less time than they would need to infect others. The amount of individuals subtracted from the susceptible group is

smaller than the amount of individuals added to the removed group:  $\frac{dS_t}{dt}$  is

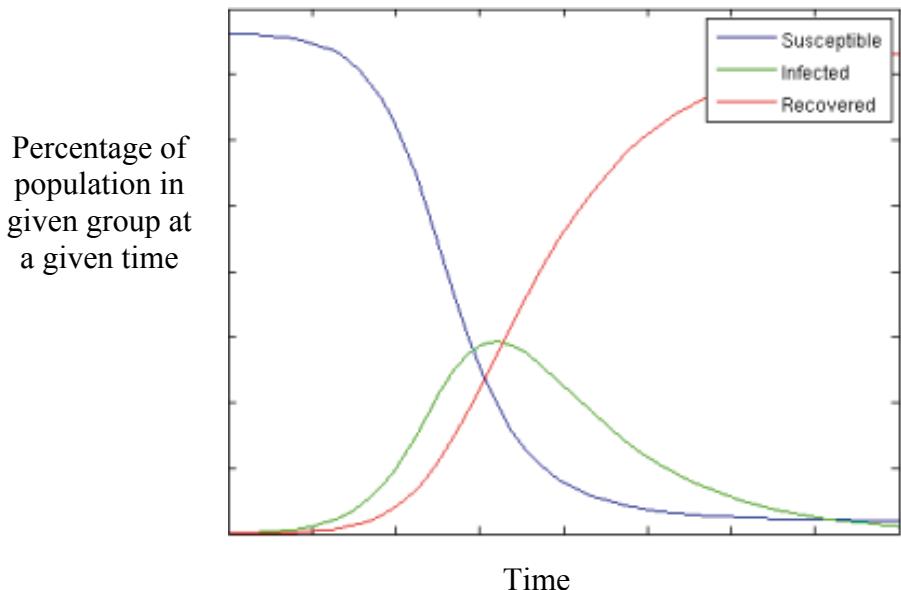
smaller than  $\frac{dR_t}{dt}$ .

### Graph Three\*

This graph was not created using the calculator; it indicates the general outline for any epidemic. We see that the percentage of susceptible subjects decreases over time, whilst the percentage of recovered (removed) subjects increases over time. The number of infected individuals progresses upwards until it reaches a local maximum where the two other graphs intersect, before the percentage of infected persons decreases again.

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\* [http://mathbio.colorado.edu/mediawiki/index.php/MBW:Stochastic\\_Epidemic](http://mathbio.colorado.edu/mediawiki/index.php/MBW:Stochastic_Epidemic)



*-Graph Three-*

## Conclusion

Our modern world is a perfect culture medium for global epidemics of contagious diseases. Predicting the spread of an epidemic is an arduous task as mathematical models cannot take into account every single factor, and uncertainties always remain that need to be dealt with. Many factors affect the spread of infectious diseases. The SIR model, devised by Kermack and McKendrick, ignores the potential births and deaths, and takes for granted an immunity that is not always present. Moreover, not every individual has the same risk of getting infected. There are many different reasons why certain individuals may be more prone than others to becoming victims of bacterial and viral transmission; responsible factors are sometimes laborious even for epidemiologists to identify and to explain.

The SIR model, despite lacking accuracy, overall provides a simple image of what can happen and may help to a certain extent to prevent major epidemics. More data must be obtained, hopefully enabling statistics to better reveal current and past trends, and to predict new outbreaks.

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